MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. XLIII. FEBRUARY 9, 1883. No. 4.

E. J. STONE, M.A., F.R.S., President, in the Chair.

A. William Dauglish, 34 Queen Anne Street, W.;
George W. H. Maclear, Royal Observatory, Cape of Good Hope; and
The Rev. Edward F. Shaw, 122 Elgin Road, Maida Vale, W.;

were balloted for and duly elected Fellows of the Society.

REPORT OF THE COUNCIL TO THE SIXTY-THIRD ANNUAL GENERAL MEETING OF THE SOCIETY.

The following table shows the progress and present state of the Society:—

	Compounders	Annual Subscribers	Non-resident	Mathematical Society	Total Fellows	Associates	Patron	Grand Total
December 31, 1881 ...	222	364	3	5	594	43	1	638
Since elected	+4	+22	...	...	...	+5	...	...
Deceased	−2	−10	−1	...	...	−2	...	...
Removals	+6	−6	...	...	...	...	...	...
Resigned	...	−7	...	...	...	...	...	...
Expelled	...	−2	...	...	...	...	...	...
December 31, 1882 ...	230	361	2	5	598	46	1	645

Mr. Barrow's Account as Treasurer of the Royal

RECEIPTS.

	£ s. d.	£ s. d.
Balance at Bankers, Jan. 1, 1882:		
Credited in pass book	601 5 1	
Cheque not credited	2 2 0	
Balance in hand of Assistant Secretary on account of Turnor Fund	13 2 9	
„ on Petty Cash account	10 3 2	
		626 13 0
Dividend on £7,500 Consols	110 3 2	
„ £5,700 New 3 per cent. Stock ...	83 14 5	
„ £7,500 Consols	110 3 2	
„ £5,700 New 3 per cent. Stock ...	83 3 9	
Interest on money on deposit at Bankers' ...	11 5 10	
		398 10 4
Received on account of Subscriptions:		
Arrears	161 14 0	
261 Contributions for 1882	548 2 0	
1 Contribution for 1883	2 2 0	
24 Admission Fees	50 8 0	
19 First Contributions	30 9 0	
		792 15 0
10 Composition Fees		210 0 0
Sales of Publications:		
At Society's Rooms, 1882	45 8 1	
At Williams & Norgate's, 1881	48 10 4	
		93 18 5
Due to Assistant Secretary on Petty Cash account, Dec. 31, 1882		2 13 7
		£2,124 10 4

Astronomical Society, from Dec. 31, 1881, to Dec. 31, 1882.

EXPENDITURE.

	£ s. d.	£ s. d.
Assistant Secretary Salary	225 0 0	
, ,, for assistance in editing Society's publications...	50 0 0	
		275 0 0
Income Tax and House Duty		9 3 9
Fire Insurance		7 16 6
Printing: Spottiswoode & Co.	490 9 0	
,, H. Richardson...	0 12 6	
		491 1 6
Computation of Ephemerides in *Monthly Notices*		12 10 0
Lithography and Engraving		19 5 10
Turnor Fund: Purchase of Books for Library ...		16 7 5
Binding Books in Library		26 17 6
House Expenses	37 19 2	
Wages	18 4 0	
Stamps and postage	54 4 2	
Carriage of books and parcels	3 19 9	
Stationery and office expenses	11 19 7	
Expenses of meetings	20 0 0	
Coals and gas	52 6 1	
Fittings, repairs, &c.	5 7 11	
Sundries	3 17 4	
		207 18 0
Mrs. Jackson-Gwilt's annuity		8 19 0
Deduction on Cheque		0 0 3
Balance at Bankers', credited in pass book, Dec. 30, 1882	514 4 9	
Amounts not credited till Jan. 1883	16 0 6	
On deposit account at Bankers	500 0 0	
		1,030 5 3
Balance in hand of Assistant Secretary on account of Turnor Fund	6 15 4	
Balance in hand of Hon. Secretary on account of payment for computation of Ephemerides...	12 10 0	
		19 5 4
		£2,124 10 4

Examined and found to be correct, Jan. 9, 1883.

F. C. Penrose,

Robt. J. Lecky.

Assets and present property of the Society, January 1, 1883 :—

	£	s.	d.	£	s.	d.
Balance at Bankers', Dec. 30, 1882, as credited in pass book	514	4	9			
Amounts not credited till Jan. 1883	16	0	6			
On deposit account at Bankers'	500	0	0			
Balance in hand of Assistant Secretary on account of Turnor Fund	6	15	4			
Balance in hand of Hon. Secretary on account of payment for computation of Ephemerides ...	12	10	0			
	1,049	10	7			
Less due to Assistant Secretary on Petty Cash account	2	13	7			
				1,046	17	0
Due on account of subscriptions :						
2 Contributions of 5 years' standing ...	21	0	0			
1 ,, 4 ,, ...	8	8	0			
13 ,, 3 ,, ...	81	18	0			
31 ,, 2 ,, ...	130	4	0			
62 ,, 1 ,, ...	130	4	0			
2 Admission fees and first contributions ...	7	7	0			
	379	1	0			
Less Contribution paid in advance ...	2	2	0			
				376	19	0
Due for Publications from Messrs. Williams & Norgate (for sales during 1882)				48	7	3
£7,500 Consols, including the Lee Fund, the Turnor Fund, and the Horrox Memorial Fund.						
£5,700 New 3 per cent. Stock, including Mrs. Jackson-Gwilt's gift (£300).						
Astronomical and other MSS., Books, Prints, Instruments, &c.						
Unsold Publications of the Society.						
Three Gold Medals.						

Report of the Auditors.

We, being two of the duly appointed Auditors, beg to lay before this General Meeting of the Royal Astronomical Society the following Report:—

1. We have examined the Treasurer's account, and an account of the assets and property of the Society, and have found and certified the same to be correct.

2. The receipts and expenditure for the past year are as stated in the Treasurer's account.

3. The cash in hand on December 31, 1882, including the balance at the bankers', amounted to 549*l.* 10*s.* 7*d.*

4. The funded property is the same as at the end of last year, and in addition, a sum of 500*l.* has been placed on deposit account at the bankers'. The books, instruments, and other effects have been examined and found in a satisfactory condition, so far as their safe keeping is concerned.

5. We have laid on the table a list of the names of those Fellows who are now in arrear for sums due at the last Annual General Meeting, with the amount due against each Fellow's name.

F. C. Penrose.
Robt. J. Lecky.

Stock in hand of volumes of the *Memoirs*:—

Vol.	At Society's Rooms	At Williams & Norgate's	Vol.	At Society's Rooms	At Williams & Norgate's
I. Part 1	6	...	XXVI.	177	...
I. Part 2	42	...	XXVII.	431	...
II. Part 1	55	...	XXVIII.	390	...
II. Part 2	20	...	XXIX.	417	...
III. Part 1	67	1	XXX.	166	...
III. Part 2	87	1	XXXI.	147	1
IV. Part 1	81	3	XXXII.	164	...
IV. Part 2	91	3	XXXIII.	169	1
V.	109	4	XXXIV.	169	6
VI.	127	3	XXXV.	112	5
VII.	153	3	XXXVI. (with M.N.)	206	11
VIII.	129	3	XXXVI. (without)	1	...
IX.	137	3	XXXVII. Part 1	350	8
X.	150	...	XXXVII. Part 2	298	8
XI.	157	...	XXXVIII.	288	2
XII.	164	...	XXXIX. Part 1	261	4
XIII.	173	1	XXXIX. Part 2	266	5
XIV.	374	3	XL.	291	3
XV.	143	...	XLI.	447	2
XVI.	170	1	XLII.	257	5
XVII.	153	2	XLIII.	268	3
XVIII.	153	...	XLIV.	255	3
XIX.	157	...	XLV.	313	2
XX.	158	...	XLVI.	356	5
XXI. Part 1	314	...	XLVII. Part 1	12	...
XXI. Part 2	99	...	XLVII. Part 2	12	...
XXI. 1 & 2 (together)	64	1	XLVII. Part 3	33	...
XXII.	159	...	Index to *Memoirs*	652	1
XXIII.	153	1			
XXIV.	161	1			
XXV.	172	...			

Stock in hand of volumes of the *Monthly Notices*:—

Vol.	At Society's Rooms	At Williams & Norgate's	Vol.	At Society's Rooms	At Williams & Norgate's
I.	74	...	XXIII.	30	...
II.	76	1	XXIV.	23	...
III.	...	...	XXV.	7	...
IV.	...	...	XXVI.	10	...
V.	...	...	XXVII.	3	...
VI.	42	...	XXVIII.	74	...
VII.	2	...	XXIX.	55	1
VIII.	140	2	XXX.	67	3
IX.	23	2	XXXI.	98	1
X.	175	1	XXXII.	122	6
XI.	186	2	XXXIII.	104	2
XII.	12	2	XXXIV.	83	2
XIII.	151	3	XXXV.	66	3
XIV.	109	3	XXXVI.	39	...
XV.	126	2	XXXVII.	41	4
XVI.	109	3	XXXVIII.	104	3
XVII.	136	1	XXXIX.	106	2
XVIII.	166	...	XL.	118	2
XIX.	58	...	XLI.	125	6
XX.	30	...	XLII.	127	8
XXI.	18	...	Index to *Monthly Notices*	588	...
XXII.	33	...			

In addition to the above volumes of the *Monthly Notices*, the Society has a considerable stock of separate numbers of nearly all the volumes. With the exception, however, of Vols. XXXVI. to XLII. no complete volumes can be formed from the separate numbers in stock.

Instruments belonging to the Society.

No. 1. The *Harrison* clock.
„ 2. The *Owen* portable circles, by Jones.
„ 3. The *Beaufoy* circle.
„ 4. The *Beaufoy* transit instrument.
„ 5. The *Herschel* 7-foot telescope.
„ 6. The *Greig* universal instrument, by Reichenbach and Ertel. The transit telescope, by Ultzschneider and Fraunhofer, of Munich.

No. 7. The *Smeaton* equatoreal.
„ 8. The *Cavendish* apparatus.
„ 9. The 7-foot Gregorian telescope (late Mr. Shearman's).
„ 10. The variation transit instrument (late Mr. Shearman's).
„ 11. The universal quadrat, by Abraham Sharp.
„ 12. The *Fuller* theodolite.
„ 13. The standard scale, by Troughton and Simms.
„ 14. The *Beaufoy* clock, No. 1.
„ 15. The *Beaufoy* clock, No. 2.
„ 16. The *Wollaston* telescope.
„ 17. The *Lee* circle.
„ 18. The *Sharpe* reflecting circle.
„ 19. The *Brisbane* circle.
„ 20. The *Baker* universal equatoreal.
„ 21. The *Reade* transit.
„ 22. The *Matthew* equatoreal, by Cooke.
„ 23. The *Matthew* transit instrument.
„ 24. The *South* transit instrument.
„ 25. A sextant, by Bird (formerly belonging to Captain Cook).
„ 26. A globe showing the precession of the equinoxes.

The *Sheepshanks* collection :—

„ 27. (1) 30-inch transit instrument, by Simms, with level and two iron stands.
„ 28. (2) 6-inch transit theodolite, with circles divided on silver; reading microscopes, both for altitude and azimuth; cross and siding levels; magnetic needle; plumbline; portable clamping foot and tripod stand.
„ 29. (3) $4\frac{6}{10}$-inch achromatic telescope, about 5 feet 6 inches focal length; finder; rack motion; double-image micrometer; two other micrometers; object-glass micrometer; one terrestrial and ten astronomical eyepieces, applied by means of two adapters; equatoreal stand, and clock movement.
„ 30. (4) $3\frac{1}{4}$-inch achromatic telescope, with equatoreal stand; double-image micrometer; one terrestrial and three astronomical eyepieces.
„ 31. (5) $2\frac{3}{4}$-inch achromatic telescope, with stand; one terrestrial and three astronomical eyepieces.
„ 33. (7) 2-foot navy telescope.
„ 34. (8) Transit instrument of 45 inches focal length; with iron stand, and also Ys for fixing to stone piers; two axis levels.
„ 35. (9) Repeating theodolite, by Ertel, with folding tripod stand.
„ 36. (10) 8-inch pillar sextant, by Troughton, divided on platinum, with counterpoise stand and artificial horizon.

No. 37. (11) Portable zenith telescope and stand, $2\frac{3}{4}$-inch aperture and 26 inches focal length; 10-inch horizontal circle and 8-inch vertical circle, read to 10″ by two verniers to each circle.

„ 38. (12) 18-inch Borda repeating circle, by Troughton, $2\frac{1}{8}$-inch aperture and 24 inches focal length; the circles divided on silver, the horizontal circle being read by four verniers, and the vertical circle by three verniers, each to 10″.

„ 39. (13) 8-inch vertical repeating circle, with diagonal telescope, by Troughton and Simms; circle divided on silver, reading to 10″; a 5-inch circle at eye-end reading to single minutes; horizontal circle 9 inches diameter in brass, reading to single minutes.

„ 40. (14) A set of surveying instruments, consisting of a 12-inch theodolite for horizontal angles only, reading to 10″; two sets of adjusting plates; tripod stand with enclosed telescope; heavy stand for theodolite; Y piece of level; two large and three small ground-glass bubbles divided; level collimator, object-glass $1\frac{5}{8}$-inch diameter and 16 inches focal length; micrometer eyepiece, comb, and wires; mercury bottle and trough.

„ 41. (15) Level collimator with object-glass $1\frac{7}{8}$-inch diameter and 16 inches focal length; stand, rider-level, and fittings.

„ 42. (16) 10-inch reflecting circle, by Troughton, reading by three verniers to 20″; counterpoise stand; artificial horizon with mercury; two tripod stands.

„ 43. (17) Hassler's reflecting circle, by Troughton, with counterpoise stand.

„ 44. (18) 6-inch reflecting and repeating circle, by Troughton and Simms, contained in three boxes, two of which form stands. Circle divided on silver, reading to single minutes; two inside arcs divided to single degrees, 150 degrees on each side; artificial horizon and mercury.

„ 45. (19) 5-inch reflecting and repeating circle, by Lenoir, of Paris.

„ 46. (20) Reflecting circle by Jecker, of Paris, 11 inches in diameter, with one vernier reading to 15″.

„ 47. (21) Box sextant; reflecting plane and level.

„ 48. (22) Prismatic compass, by Troughton and Simms.

„ 49. (23) Mountain barometer.

„ 50. (24) Prismatic compass, by Thomas Jones, mounted with a cylindrical lens.

51. (25) Ordinary $4\frac{1}{2}$-inch compass with needle.

„ 52. (26) Dipping needle, by Robinson.

„ 53. (27) Compass needle, mounted for variation.

„ 54. (28) Magnetic intensity needle, by Meyerstein, of

Göttingen; a strongly fitted brass box with heavy magnet; filar suspension.

No. 55. (29) Box of magnetic apparatus.

„ 56. (30) Hassler's reflecting circle, by Troughton; a 10½-inch reflecting and repeating circle, with stand and counterpoise, divided on platinum with two movable and two fixed indices; four verniers reading to 10″.

„ 57. (31) Box sextant and glass plane artificial horizon, by Troughton and Simms.

„ 58. (32) Plane 2⅜-inch speculum, artificial horizon, and stand.

„ 59. (33) 2½-inch circular level horizon, by Dollond.

„ 60. (34) Artificial horizon, roof, and trough; the trough 8¼ by 4½ inches: tripod stand.

„ 61. (35) Set of drawing instruments, consisting of 6-inch circular protractor and common protractor, T-square: one beam compass.

„ 62. (36) A pentagraph.

„ 63. (37) A noddy.

„ 64. (38) A small Galilean telescope with object-glass of rock crystal.

„ 65. (39) Five levels.

„ 66. (40) 18-inch celestial globe.

„ 67. (41) Varley stand for telescope.

„ 69. (43) Telescope, with the object-glass of rock crystal.

„ 70. Portable equatoreal stand.

„ 71. Portable altazimuth tripod.

„ 72. Four polarimeters.

„ 74. Registering spectroscope, with one large prism.

„ 76. Two five-prism direct-vision spectroscopes.

„ 78. 9¼-inch silvered-glass reflector and stand, by Browning.

„ 79. Spectroscope.

„ 80. A small box, containing three square-headed Nicol's prisms; two Babinet's compensators; two double-image prisms; three Savarts; one positive eyepiece, with Nicol's prism; one dark wedge.

„ 81. A back-staff, or Davis' quadrant.

„ 82. A nocturnal or star dial.

„ 83. An early non-achromatic telescope, of about 3 feet focal length, in oak tube, by Samuel Scatliffe, London.

„ 84. A Hollis observing chair.

„ 85. Double image micrometer, by Troughton and Simms.

„ 86. 4½-inch Gregorian reflecting telescope, by Short, with altazimuth stand and 6-inch altitude and azimuth circles and two eyepieces.

„ 87. 3¼-inch Gregorian reflecting telescope with wooden tripod stand.

No. 88. Pendulum with 5-foot brass suspension rod, working on knife edges, by Thomas Jones.
,, 89. A Rhabdological Abacus. A contrivance invented by Mr. H. Goodwyn, consisting of a box filled with compartments, in which are square rods covered with numbers, which can be arranged so as to facilitate the labour of multiplying high numbers.
,, 90. An Arabic celestial globe of bronze, not quite 6 inches in diameter.
,, 91. Astronomical time watchcase, by Professor Chevallier.
,, 92. 2-foot protractor, with two moveable arms, and vernier.
,, 93. Beam compass, in box.
,, 94. 2-foot navigation scale.
,, 95. Stand for testing measures of length.
,, 96. Artificial planet and star, for testing the measurement of a fixed distance at different position-angles.
,, 97. 12-cell Leclanché battery.
,, 98. 2 feet 6 inch navy telescope with object-glass $2\frac{1}{2}$ inches, by Cooke, with portable wooden tripod stand.
,, 99. 12-inch transit instrument, by Fayrer & Son, with level and portable stand.
,, 100. 9-inch transit instrument, with level and iron stand.
,, 101. Small equatoreal sight instrument, by G. Adams, London.
,, 102. Sun-dial, by Troughton.
,, 103. Sun-dial, by Casella.
,, 104. Sun-dial.
,, 105. Box sextant, by Troughton and Simms.
,, 106. Prismatic compass, by Schmalcalder, London.
,, 107. Compass, by C. Earle, Melbourne.
,, 108. Prismatic compass, by Negretti and Zambra.
,, 109. Dipleidoscope, by E. Dent.
,, 110. Abney level, by Elliott.
,, 111. Pocket spectroscope, by Browning.
,, 112. Small brass astrolabe.
,, 113. Double sextant, by Jones.
,, 114. Two models, illustrating the effects of circular motions.
,, 115. A cometarium.
,, 116. A pair of 18-inch globes.

The following instruments are lent, during the pleasure of the Council, to the undermentioned persons :—

No. 4. The *Beaufoy* transit instrument, to the Observatory, Kingston, Canada.
„ 23. The *Matthew* transit, to Captain Noble.
„ 74. Registering spectroscope, with prism, to Mr. Lecky.
„ 75. One five-prism direct vision spectroscope, to Colonel de Rottenburg.

From the *Sheepshanks* collection :—

No. 30. (4) 3¼-inch equatoreal and stand, to Mr. Sadler.
„ 34. (8) Transit instrument, to the Rev. Professor Pritchard.
„ 69. (43) Telescope, with rock-crystal object-glass, to Dr. Huggins.

The telescope and eyepieces of No. 29 (3), and the portable equatoreal stand No. 70, which were lent to the Transit of *Venus* Committee, and were used in observing the Transit at Bermuda, were lost in the S.S. "City of Brussels," on January 7, 1883.

The Gold Medal.

The Council have awarded the Society's Gold Medal to Dr. B. A. Gould for his *Uranometria Argentina*. The President will lay before the Society the grounds upon which this award has been founded.

Publications of the Society.

Vol. XLVII. of the *Memoirs* is in course of publication. It will contain the following papers :—

Professor C. Pritchard. On the Moon's Photographic Diameter, and on the Applicability of Celestial Photography to Accurate Measurement.

Observations of the Transit of *Venus*, 1874, December 8–9, made in Victoria, New South Wales, South Australia, at Mooltan, and at the Cape of Good Hope.

H. C. Russell. Measures of Sir John Herschel's Cape Stars, together with a List of new Double Stars.

S. W. Burnham. Double-star Observations made in 1879 and 1880 with the 18½-inch Refractor of the Dearborn Observatory, Chicago.

Obituary.

The Council regret that they have to record the loss by death of the following Fellows and Associates during the past year:—

Fellows:—C. E. Burton.
Rev. J. Challis.
A. Cooper.
W. A. Cross.
H. Dodgson.
Rev. W. H. Drew.
S. Heywood.
R. C. May.
E. H. Pringle.
Rev. T. R. Robinson.
Prof. H. J. S. Smith.
C. V. Walker.
T. Warner.
Major-Gen. W. K. Worster.

Associates:—E. Plantamour.
J. F. K. Zöllner.

Charles E. Burton was the son of the Rev. E. Burton, Rector of Rathmichael, in County Dublin. He graduated at Trinity College, Dublin, and was for some years the assistant to the Earl of Rosse at Parsonstown, where he learned the rudiments of the art of speculum-grinding, in which he afterwards became proficient, some of his specula, silver on glass, of from 6 to 15 inches diameter, being unsurpassed. Their excellence, as well as Mr. Burton's skill in delineating, is shown by the views of *Mars* lately published by the Royal Irish Academy. The observations on which the views were founded were made with 8- and 12-inch specula, which were wholly the work of Mr. Burton's own hands. Very shortly before his death he was engaged in taking photographs of the Moon directly enlarged by means of an eyepiece. For this purpose he employed the $7\frac{1}{2}$-inch Equatorial of his friend Dr. Erck, with an inch eyepiece. The diameter of the Moon's disk thus directly enlarged was about 10 inches, and the exposure from 8 to 16 seconds. His experiments in this direction were interrupted by his preparations for the Transit of *Venus* Expedition to the Cape of Good Hope. He died suddenly on July 9, 1882, from heart disease, at the early age of thirty-five. The number of the *Monthly Notices* for last June contains two short papers by him, which are dated June 5 and 6, 1882. He also at one time paid considerable attention to the question of earth currents in telegraph wires, and contributed two papers to the *Philosophical Transactions*, in which observations made on the South Eastern Railway were discussed, and the results compared with the

magnetic changes observed at the Greenwich Observatory. He was elected a Fellow of the Society on May 8, 1874.

James Challis was the fourth son of Mr. John Challis, of Braintree, Essex, where he was born on December 12, 1803. He first went to Braintree school, where, as he used often to say himself, he soon learned all that they could teach him. He then went for a short time to a small school kept in Braintree by the Rev. Daniel Copsey, who was afterwards author of *Essays on Moral and Religious Subjects* (1821), *Studies in Religion* (1826), and other works. Seeing his talent Mr. Copsey, in conjunction with Mr. Matthews, vicar of Coggeshall, sent him to try for a presentation to Mill Hill School, near London, which he succeeded in obtaining by examination. Before proceeding to the University he read for a time with Mr. Matthews.

In October 1821 he entered Trinity College, Cambridge, as a sizar. He was elected a scholar in 1824, and in 1825 he graduated as senior wrangler, being also first Smith's prizeman. The same tripos list contains the name of Sir J. W. Lubbock, whose researches in the Lunar Theory are well known. In the following year Challis was elected Fellow of Trinity, and he resided in the college until he was ordained in 1830, when he was presented to the college living of Papworth Everard, which he held until 1852. He held no college office except during the last two years of his residence, when he took part in the college examinations. The vacations he spent with pupils in the Isle of Wight, Wales, and the English Lakes, once also visiting France. In 1831 he vacated his Fellowship by marriage with the widow of Mr. Daniel Copsey, second daughter of Mr. Samuel Chandler, of Tyringham in Buckinghamshire. He was re-elected Fellow of Trinity in 1870, and was a Fellow at the time of his death.

On February 2, 1836 he was elected Plumian Professor of Astronomy and Experimental Philosophy in the University, in succession to Professor Airy, who had been appointed Astronomer Royal. Mr. Challis was also at the same time made Director of the Cambridge Observatory, where he resided for the next five-and-twenty years, diligently engaged in making and reducing astronomical observations, and where he dispensed, in conjunction with Mrs. Challis, a kindly hospitality that is well remembered by Cambridge men of that time. He resigned the directorship of the Observatory in 1861, when he was succeeded by Professor Adams; but he retained the Plumian Professorship and resided in Cambridge till his death. From 1843 until within the last three or four years he always lectured on Practical Astronomy and the Use of Astronomical Instruments, and when his health became impaired and he was no longer able to lecture himself, he appointed as his deputy Mr. Freeman, late Fellow of St. John's College, who lectured for him on these subjects. Professor Challis was a man of kindly disposition and of simple and courteous manners. His strength gradually

declined in the last few years of his life, and during the last year he was very weak, and it seemed as if death might come at any moment. He quietly passed away on Sunday, December 3, 1882, when within a few days of completing his seventy-ninth year. He was buried on Friday, December 8, at the Mill Road Cemetery, Cambridge, in the same grave with his wife.

Professor Challis was one of those who played a conspicuous part in what is not only the most important episode in the short history of the Cambridge Observatory, but perhaps the most striking event in the long records of Astronomy itself—the discovery of the planet *Neptune*. It is true that the planet was actually discovered at Berlin through Leverrier's predictions, quite independently of what had taken place at Cambridge, but it is true also that Adams had predicted the planet's place, and that Challis, looking in the place predicted, had actually twice seen the planet through the Northumberland Equatorial at Cambridge six weeks before the Berlin telescope was ever directed to the sky to look for it. The accidental possession of one of Bremiker's star-maps enabled Dr. Galle to detect the planet on the night on which he began the search; but the systematic and excellent method followed by Challis must soon have led to its discovery. It is difficult, perhaps, not to feel some regret that one who was so nearly successful, and who so well deserved success, should not have been enabled to announce to the world the actual discovery, and that the greatest of the triumphs of the Newtonian principles should not have been absolutely completed in the University where they had their birth; but so far from attributing any trace of blame to Professor Challis, one can scarcely admire too highly the zeal, industry, and conscientiousness which he brought to bear upon a research quite without precedent in the history of astronomy. He fully recognised the importance of the question, and showed no want of faith in the results obtained by refined and laborious analytical processes. On the contrary, he took every measure to secure the success of his undertaking, and success must have rewarded his efforts, had not their continuance been suddenly rendered unnecessary. The history of the discovery of the planet *Neptune* is given in three papers, all read before the Society on November 13, 1846, and printed in Vol. XVI. of the *Memoirs*. The first by the Astronomer Royal, which is entitled "Account of some Circumstances historically Connected with the Discovery of the Planet exterior to *Uranus*," appeared also in vol. vii. of the *Monthly Notices*. In the second Professor Challis gives an account of his observations at the Cambridge Observatory for the purpose of detecting the planet, and the third is Professor Adams's own paper, containing his mathematical investigations.*

* To secure more speedy publication, this paper was also issued with the *Nautical Almanac* for 1851, and copies of it were circulated with the number of the *Astronomische Nachrichten* for March 27, 1847.

The following *résumé* of the events relating to the investigations that preceded the discovery of the planet has been principally derived from these papers. It is well known that there were matters which gave rise to controversy at the time, but these are not referred to in what follows, only the essential facts being given. It is scarcely necessary to state that there is absolutely no doubt that the investigations of Adams and Leverrier were quite independent.

In 1841, Adams, then an undergraduate at St. John's College in his second year, formed the design of investigating the inequalities in the motion of *Uranus* that were still unaccounted for, as soon as he should have taken his degree. He graduated as senior wrangler in 1843, and at once attacked the problem. In February 1844 he asked Professor Challis to obtain from Mr. Airy, the Astronomer Royal, the errors in the tabular geocentric longitudes of *Uranus* for 1818–1826, with the factors for reducing them to errors of heliocentric longitude. These Professor Challis applied for, and the Astronomer Royal forwarded to him all the heliocentric errors of *Uranus* in longitude and latitude from 1754 to 1830. In September 1845, Adams called upon Professor Challis, and gave him a paper containing numerical values of the mean longitude at a given epoch, longitude of perihelion, eccentricity, mass and geocentric longitude of the new planet. On September 22, 1845, Professor Challis wrote a letter of introduction to the Astronomer Royal, beginning: "My friend Mr. Adams, who will probably deliver this note to you, has completed his calculations respecting the perturbation of the orbit of *Uranus* by a supposed ulterior planet, and has arrived at results which he would be glad to communicate to you, if you could spare him but a few moments of your valuable time." Adams called at Greenwich in September and October, but on neither occasion was he successful in seeing Mr. Airy, who at the time of the first visit was absent in France. At his second visit he left a paper, giving the following values of the mass and the orbit of the new planet:—

Mean Distance (assumed nearly in accordance with Bode's law)	38·4
Mean Sidereal Motion in 365·25 days	1° 30′·9
Mean Longitude, 1845, Oct. 1	323 34
Longitude of Perihelion	315 55
Eccentricity	0·1610
Mass (that of the Sun being unity)	0·0001656

This was accompanied by the list of the residual errors from 1690 to 1840, when the disturbance of the new planet was taken account of, the errors being very small, except in the case of Flamsteed's observation of 1690.

Some months later, in the number of the *Comptes Rendus*

for June 1, 1846, Leverrier gave reductions of the existing observations of *Uranus*, and concluded that the observations were irreconcilable with theory, and that there was no other possible explanation of the discrepancy except that of a disturbing planet exterior to *Uranus*. He investigated the elements of the orbit of such a planet, its mean distance being assumed to be double that of *Uranus*, and its orbit being in the plane of the ecliptic. The value of the mean distance was suggested by Bode's law. Leverrier gave, as the most probable result of his investigations, that the true longitude of the disturbing planet for the beginning of 1847 must be about 325°, and that an error of 10° in this place was not probable. No elements of the orbit or mass of the planet were given. On July 9, 1846, Mr. Airy wrote to Professor Challis from the Deanery, Ely, suggesting that search should be made for the planet with the Northumberland Equatorial, and offering the services of an assistant; and on July 13 he transmitted to him certain suggestions with regard to the proposed sweeps for the planet. On July 18, Professor Challis wrote to the Astronomer Royal: "I have only just returned from my excursion. . . . I have determined on sweeping for the hypothetical planet. . . . With respect to your proposal of supplying an assistant I need not say anything, as I understand it to be made on the supposition that I decline making the search myself. . . . I purpose to carry the sweep to the extent you recommend." On August 7 Professor Challis wrote to Mr. Main, in the supposed absence of the Astronomer Royal, saying that he had undertaken the search for the new planet, and that he had made trial of two methods of observing. In the one recommended by Mr. Airy he had met with a difficulty, as he had anticipated, and he had therefore adopted another method.

On September 2 Professor Challis wrote to Mr. Airy: "I have lost no opportunity of searching for the planet; and, the nights having been generally pretty good, I have taken a considerable number of observations: but I get over the ground very slowly, thinking it right to include all stars to 10–11 magnitude; and I find that to scrutinise thoroughly in this way the proposed portion of the heavens will require many more observations than I can take this year." On the same day (September 2) Adams wrote to the Astronomer Royal a letter, the opening paragraphs of which are as follows: "In the investigation the results of which I communicated to you last October, the mean distance of the supposed disturbing planet is assumed to be twice that of *Uranus*. Some assumption is necessary in the first instance, and Bode's law renders it probable that the above distance is not very remote from the truth: but the investigation could scarcely be considered satisfactory while based on anything arbitrary; and I therefore determined to repeat the calculation, making a different hypothesis as to the mean distance. The eccentricity also resulting from my former calculations was far too large to

be probable; and I found that, although the agreement between theory and observation continued very satisfactory down to 1840, the difference in subsequent years was becoming very sensible, and I hoped that these errors as well as the eccentricity might be diminished by taking a different mean distance. Not to make too violent a change, I assumed this distance to be less than the former value by about $\frac{1}{30}$th part of the whole. The result is very satisfactory, and appears to show that, by still further diminishing the distance, the agreement between the theory and the later observations may be rendered complete, and the eccentricity reduced at the same time to a very small quantity. The mass and the elements of the orbit of the supposed planet, which result from the two hypotheses, are as follows :—

	Hypothesis I. $\left(\frac{a}{a'}=0{\cdot}5\right)$	Hypothesis II. $\left(\frac{a}{a'}=0{\cdot}515\right)$
Mean Longitude of Planet, 1846, Oct. 1 ...	325° 8′	323° 2′
Longitude of Perihelion	315° 57′	299° 11′
Eccentricity	0·16103	0·12062
Mass (that of Sun being 1)	0·00016563	0·00015003

He also adds the errors of mean longitude, exhibiting the difference between theory and observation on the two hypotheses, and after pointing out that the errors given by the Greenwich Observations of 1843 are very sensible on both hypotheses, he proceeds: "By comparing these errors it may be inferred that the agreement of theory and observation would be rendered very close by assuming $\frac{a}{a'}=0{\cdot}57$, and the corresponding mean longitude on October 1, 1846, would be about 315° 20′, which I am inclined to think is not far from the truth. It is plain, also, that the eccentricity corresponding to this value of $\frac{a}{a'}$ would be very small." In consequence of the divergence of the results Adams asked for two normal places near the oppositions of 1844 and 1845. In the Astronomer Royal's absence these were sent by Mr. Main; and on September 7 Adams wrote: "I hope by to-morrow to have obtained approximate values of the inclination and longitude of the node."

But on August 31 Leverrier's second paper on the place of the disturbing planet had been communicated to the French Academy. The number of the *Comptes Rendus* containing this paper could not reach this country until the third or fourth week in September, and it does not appear that any earlier notice of its contents was received in England.

The elements given by Leverrier are—

Semi-axis Major	36·154 $\left(\text{or } \frac{a}{a'} = 0{\cdot}531\right)$
Periodic Time	217·387
Eccentricity	0·10761
Longitude of Perihelion	284° 45′
Mean Longitude, 1847, Jan. 1	318° 47′
Mass	$= \frac{1}{9300} = 0{\cdot}0001075$
True Heliocentric Longitude, 1847, Jan. 1	326° 32′
Distance from the Sun	33·06

Leverrier gave also comparisons between theory and observation, and he concluded that the planet would have a visible disk and sufficient light to make it conspicuous in ordinary telescopes.

In a letter received at Berlin on September 23, Leverrier invited Dr. Galle to search for the planet, suggesting that it might be recognised by its disk. The same evening Dr. Galle examined the heavens, comparing the stars with Dr. Bremiker's map (Hora xxi. of the Berlin Academy's Star Maps). He soon found a star of about the eighth magnitude, nearly in the place pointed out by Leverrier, which did not exist in the map. There could be little doubt that this was the new planet, and the observations of the two days following showed that its motion was nearly the same as that of the planet predicted. The finding of the planet was due to Dr. Bremiker's map: the disk could not easily be recognised before its existence was known.

It seems but just to Professor Challis that the following report, which he drew up for the Cambridge Observatory Syndicate, and which was printed at the time by them, should now be placed permanently on record as giving his own account of the circumstances attending the search for the planet at Cambridge. The report is dated December 12, 1846, and the preamble, which is signed by the syndics, runs: "The syndicate appointed to visit the Observatory, conceiving the subject at the present time to possess peculiar interest, beg leave to submit to the Senate the following statement of Professor Challis, describing the course of observations, founded on the theoretical calculations of Mr. Adams, of St. John's College, and made at the Observatory with a view to the discovery of the new planet." Professor Challis's report is as follows:—

"At a meeting of the Observatory Syndicate, held at the Observatory on December 4, for the despatch of ordinary business, a strong desire having been expressed by the Vice-Chancellor and the members of the Syndicate generally, to receive from me a Special Report of Observatory proceedings

relating to the newly-discovered Planet, drawn up in such a manner, and in such detail, as would enable them to lay complete information on the subject before the members of the Senate, I considered it to be my duty at once to comply with this request. A new body of the solar system has been discovered, by means depending on the farthest advances hitherto made in theoretical and practical astronomy, and confirming, in a most remarkable manner, the theory of universal gravitation. It is, therefore, on every account desirable that the members of the Senate should be made fully acquainted with the part which has been taken by the Cambridge Observatory, relatively to this important extension of astronomical science. The observations I shall have to speak of, and the reasons for undertaking them, are so closely connected with theoretical calculations performed by a member of this University, to account for anomalies in the motion of the planet *Uranus*, that the history of the former necessarily involves that of the latter. I hope that for this reason, and because of the peculiar nature of the circumstances, I may be allowed to make a communication less formal and restricted in its character, than a mere Report of Observatory proceedings.

"The tables with which the observations of the planet *Uranus* have been uniformly compared, were published by A. Bouvard in 1821. They are founded on a continued series of observations extending from 1781, the year of its discovery, to 1821. Previous to 1781, it had been accidentally observed seventeen times as a fixed star, the earliest observation of this kind being one by Flamsteed in 1690. Bouvard met with a difficulty in forming his Tables. On an attempt to found them upon the ancient, as well as the modern, observations, it appeared that the theoretical did not agree with the observed course of the planet. He thought this might be attributed to the imperfection of the ancient observations, and consequently rejected all previous to 1781, in the formation of the Tables finally published. These Tables represent well enough the observations in the forty years from 1781 to 1821; but very soon after the latter year, new errors began to show themselves, which have gone on increasing to the present time. It was now evident that the ancient observations had been rejected on insufficient grounds, and that from some unknown cause the theory was in fault. Were the Tables calculated inaccurately? The difference between observation and theory (amounting in 1841 to 96″ of geocentric longitude) was too great, and Bouvard's calculations were made with too much care to allow of this explanation. The effect of small terms neglected in the calculation of the perturbations caused by *Jupiter* and *Saturn*, could not be supposed to bear any considerable proportion to the observed amount of error. This state of the theory suggested to several astronomers the idea of disturbances, caused by an undiscovered planet more distant than *Uranus*. But there is no evidence of this hypothesis having been put to the test of calculation pre-

vious to 1843. The usual problem of perturbations is to find the disturbing action of one body on another, by knowing the positions of both. Here an inverse problem, hitherto untried, was to be solved; viz. from known disturbances of a planet in known positions, to find the place of the disturbing body at a given time. Mr. Adams, Fellow of St. John's College, showed me a memorandum made in 1841, recording his intention of attempting to solve this problem as soon as he had taken his degree of B.A. Accordingly, after graduating in January 1843, he obtained an approximate solution by supposing the disturbing body to move in a circle at twice the distance of *Uranus* from the Sun. The result so far satisfied the observed anomalies in the motion of *Uranus*, as to induce him to enter upon an exact solution. For this purpose he required reduced observations made in the years 1818–1826, and requested my intervention to obtain them from Greenwich. The Astronomer Royal, on my application, immediately supplied (February 15, 1844), all the heliocentric errors of *Uranus* in longitude and latitude, from 1754 to 1830, completely reduced. Mr. Adams was now furnished with ample data from observation, and his next care was to ascertain whether Bouvard's theoretical calculations were correct enough for his purpose. He tested the accuracy of the principal terms of the perturbations caused by *Jupiter* and *Saturn*, and concluded that the small terms which Bouvard had not taken into account would not sensibly affect the final results, the chief of them being either of long period or of a period nearly equal to that of *Uranus*. Besides which he introduced into the theory several corrections which had been derived from observation and calculation by different astronomers since 1821. The calculations were completed in 1845. In September of that year, Mr. Adams placed in my hands a paper containing numerical values of the mean longitude at a given epoch, longitude of perihelion, eccentricity of orbit, mass, and geocentric longitude, September 30, of the supposed disturbing planet, which he calls by anticipation 'The New Planet,' evidently showing the conviction in his own mind of the reality of its existence. Towards the end of the next month, a communication of results slightly different was made to the Astronomer Royal, with the addition of what was far more important, viz. a list of the residual errors of the mean longitude of *Uranus*, for a period extending from 1690 to 1840, after taking account of the disturbing effect of the supposed planet. This comparison of observation with the theory implied the determination of *all* the unknown quantities of the problem, both the corrections of the elements of *Uranus* and the elements of the disturbing body. The smallness of the residual errors proved that the new theory was adequate to the explanation of the observed anomalies in the motion of *Uranus*, and that as the error of longitude was corrected for a period of at least 130 years, the error of radius vector was also corrected. As the calculations rested on an

assumption, made according to Bode's law, that the mean distance of the disturbing planet was double that of *Uranus*, without the above-mentioned numerical verification, no proof was given that the problem was solved or that the elements of the supposed planet were not mere speculative results. The earliest evidence of the complete solution of an inverse problem of perturbations is to be dated from October 1845.

"Although the comparison of the theory with observation proved synthetically that the assumed mean distance was not very far from the truth, it was yet desirable to try the effect of an alteration of the mean distance. Mr. Adams accordingly went through the same calculations as before, assuming a mean distance something less than the double of that of *Uranus*, and obtained results which indicated a better accordance of the theory with observation, and led him to the conclusion, which has since been confirmed by observation, that the mean distance should be still farther diminished. This second solution taken in conjunction with the first may be considered to relieve the question of every kind of assumption. The new elements of the disturbing body, and the results of comparing the observed with the theoretical mean longitudes of *Uranus*, were communicated to the Astronomer Royal at the beginning of September 1846. These were accompanied by numerical values of errors of the radius vector, the Astronomer Royal having inquired, after the reception of the first solution, whether the error of radius vector, known to exist from observation, was explained by this theory. It would be wrong to infer that Mr. Adams was not prepared to answer this question till he had gone through the second solution. Errors of radius vector were as readily deducible from the first solution as from the other.

"The preceding details are intended to point out the circumstances which led astronomers to suspect the existence of an additional body of the solar system, and the theoretical reasons there were for undertaking to search for it. No one could have anticipated that the place of the unknown body was indicated with any degree of exactness by a theory of this kind. It might reasonably be supposed, without at all mistrusting the evidence which the theory gave of the *existence* of the planet, that its position was determined but roughly, and that a search for it must necessarily be long and laborious. This was the view I took, and consequently I had no thought of commencing the search in 1845, the planet being considerably past opposition at the time Mr. Adams completed his calculations. The succeeding interval to midsummer of 1846 was a period of great astronomical activity, the planet *Astræa*, Biela's double comet, and several other comets, successively demanding attention. During this time I had little communication with Mr. Adams respecting the new planet. Attention was again called to the subject by the publication of M. Leverrier's first researches in the *Comptes Rendus* for June 1, 1846. At a meeting of the Green-

wich Board of Visitors held on June 29, at which I was present, Mr. Airy announced that M. Leverrier had obtained very nearly the same longitude of the supposed planet as that given by Mr. Adams. On July 9 I received a letter from Mr. Airy, in which he suggested employing the Northumberland Telescope in a systematic search for the planet, offering at the same time to send an assistant from Greenwich, in case I declined undertaking the observations. This letter was followed by another dated July 13, containing suggestions respecting the mode of conducting the observations, and an estimation of the amount of work they might be expected to require. In my answer, dated July 18, I signified the determination I had come to of undertaking the search. Various reasons led me to this conclusion. I had already, as Mr. Adams can testify, entertained the idea of making these observations; the most convenient time for commencing them was now approaching; and the confirmation of Mr. Adams's theoretical position by the calculations of M. Leverrier appeared to add very greatly to the probability of success. I had no answer to make to Mr. Airy's offer of sending an assistant, as I understood the acceptance of it to imply the relinquishing on my part of the undertaking.

"I have now to speak of the observations. The plan of operations was formed mainly on the suggestions contained in Mr. Airy's note of July 13. It was recommended to sweep over, three times at least, a zodiacal belt 30° long and 10° broad, having the theoretical place of the planet at its centre; to complete one sweep before commencing the next; and to map the positions of the stars. The three sweeps, it was calculated, would take 300 hours of observing. This extent of work, which will serve to show the idea entertained of the difficulty of the undertaking before the planet was discovered, did not appear to me greater than the case required. It will be seen that the plan did not contemplate the use of hour XXI. of the Berlin Star Maps, the publication of which was equally unknown at that time to Mr. Airy and myself. It may be proper here to explain that the construction of a good star-map requires a great amount of time and labour both in observing and calculating, and that precisely this sort of labour must be gone through to conduct a search of the kind I had undertaken. The stars must first be mapped before the search can properly be said to begin. With a map ready made, the detection of a moving body, as it happened in this instance, might be effected on a comparison of the heavens with the map by mere inspection. Not having the advantage of such a map, I proceeded as follows. I noted down very approximately the positions of all the stars to the 11th magnitude that could be conveniently taken as they passed through the field of view of the telescope, the breadth of the field with a magnifying power of 166 being 9′, and the telescope being in a fixed position. When the stars came thickly, some were necessarily allowed to pass without recording their places. Wishing to

include *all* stars of the 11th magnitude, I proposed, in going over the same region a second time, to avail myself of an arrangement peculiar to the Northumberland Equatorial, the merit of inventing which is due to Mr. Airy. The Hour-circle, Telescope, and Polar Frame are movable by clockwork, which may be regulated to sidereal time nearly. While this motion is going on, the Telescope and Polar Frame are movable *relatively to the Hour-circle*, by a tangent-screw apparatus, and a handle extending to the observer's seat. This contrivance enables the observer to measure at his leisure differences of Right Ascension however small, and therefore meets the case of stars coming in groups. The observations made by this method might include all the stars it was thought desirable to take, and therefore might include *all* the stars taken in the first sweep. The discovery of the planet would result from finding that any star in the first sweep was not in its position in the second sweep. If two sweeps failed in detecting the planet among the stars of the first sweep, it might be among the stars of the second, which would be decided by taking a third sweep of the same kind as the second. It will appear that this plan carried out would not only detect the planet if it were in the region explored, but would also, in case of failure, enable the observer to pronounce that it was not in that region. The second mode of observing required the aid of my two assistants, Mr. Morgan and Mr. Breen, in reading off and recording the observations.

"I commenced observing July 29, employing on that day the first method, with telescope fixed. The next day I observed according to the second method, with telescope moving. On August 4, the telescope was fixed as to Right Ascension, but was moved in Declination in a zone of about 70′ breadth, the intention of the observations of that day being to record points of reference for the zones of 9′ breadth. On August 12, the fourth day of observing, I went over the same zone, telescope fixed, as on July 30 with telescope moving. Soon after August 12, I compared, to a certain extent, the observations of that day, with the observations of July 30, taken with telescope moving; and finding, as far as I carried the comparison, that the positions of July 30 included *all* those of August 12, I felt convinced of the adequacy of the method of search I had adopted. The observations were continued with diligence to September 29, chiefly with telescope fixed, and were made early in Right Ascension for the purpose of exploring as large a space as possible before I should be compelled to desist by the approach of daylight. On October 1 I heard that the planet was discovered by Dr. Galle, at Berlin, on September 23. I had then recorded 3150 positions of stars, and was making preparations for mapping them. The following results were obtained by a discussion of the observations after the announcement of the discovery.

"On continuing the comparison of the observations of July 30 and August 12, I found that No. 49, a star of the 8th magnitude

in the series of August 12, *was wanting in the series of July* 30. According to the principle of the search, this was the planet. It had wandered into the zone in the interval between July 30 and August 12. I had not continued the former comparison beyond No. 39, probably from the accidental circumstance that a line was there drawn in the memorandum-book in consequence of the interruption of the observations by a cloud. After ascertaining the place of the planet on August 12, I readily inferred that it was also among the reference stars taken on August 4. Thus, after four days of observing, two positions of the planet were obtained. This is entirely to be attributed to my having, on those days, directed the telescope towards the planet's theoretical place, according to instructions given in a paper Mr. Adams had the kindness to draw up for me. I would also beg to call attention to the fact that, after August 12, the planet was discoverable by a closet-comparison of the observations, a method of observing, depending on novel and ingenious mechanism, having been adopted, by which I could say of each star, to No. 48, 'This is not a planet,' and of No. 49, 'This *is* a planet.' I lost the opportunity of announcing the discovery by deferring the discussion of the observations, being much occupied with reductions of comet observations, and little suspecting that the indications of theory were accurate enough to give a chance of discovery in so short a time. On September 29 I saw, for the first time, the communication presented by M. Leverrier to the Paris Academy on August 31. I was much struck with the manner in which the author limits the field of observation; and with his recommending the endeavour to detect the planet by its disk. Mr. Adams had already told me that, according to his estimation, the planet would not be less bright than a star of the ninth magnitude. On the same evening I swept a considerable breadth in Declination, between the limits of Right Ascension marked out by M. Leverrier, and I paid particular attention to the physical appearance of the brighter stars. Out of 300 stars, whose positions I recorded that night, I fixed on one which appeared to have a disk, and which proved to be the planet. This was the third time it was observed before the announcement of the discovery reached me. This last observation may be regarded as a discovery of the planet, due to the good definition of the noble instrument which we owe to the munificence of our Chancellor.

"From the reduced places of the planet, on August 4 and August 12, and from observations since its discovery extending to October 13, Mr. Adams calculated, at my request, values of its heliocentric longitude at a given epoch, its actual distance from the Sun, longitude of the node, and inclination of the orbit, which were published as early as October 17. I am now diligently observing the planet with the meridian instruments, and when daylight prevents its being seen on the meridian, I propose carrying on the observations as long as possible with the

Northumberland Equatorial, for the purpose of obtaining data for a further approximation to the elements of the orbit.

"My report of proceedings relating to the planet here terminates. I beg permission to add a few remarks, which the facts I have stated seem to call for. It will appear by the above account, that my success might have been complete, if I had trusted more implicitly to the indications of the theory. It must, however, be remembered, that I was in quite a novel position: the history of astronomy does not afford a parallel instance of observations undertaken entirely in reliance upon deductions from theoretical calculations, and those too of a kind before untried. As the case stands, a very prominent part has been taken in the University of Cambridge, with reference to this extension of the boundaries of astronomical science. We may certainly assert to be facts, for which there is documentary evidence, that the problem of determining, from perturbations, the unknown place of the disturbing body, was first solved here; that the planet was here first sought for; that places of it were here first recorded; and that approximate elements of its orbit were here first deduced from observation. And that all this may be said, is entirely due to the talents and labours of one individual among us, who has at once done honour to the University, and maintained the scientific reputation of the country. It is to be regretted that Mr. Adams was more intent upon bringing his calculations to perfection, than on establishing his claims to priority by early publication. Some may be of opinion, that in placing before the first astronomer of the kingdom results which showed that he had completed the solution of the problem, and by which he was, in a manner, pledged to the production of his calculations, there was as much publication as was justifiable on the part of a mathematician whose name was not yet before the world, the theory being one by which it was possible the practical astronomer might be misled. Now that success has attended a different course, this will probably not be the general opinion. I should consider myself to be hardly doing justice to Mr. Adams, if I did not take this opportunity of stating, from the means I have had of judging, that it was impossible for any one to have comprehended more fully and clearly all the parts of this intricate problem; that he carefully considered all that was necessary for its exact solution; and that he had a firm conviction, from the results of his calculations, that a planet was to be found."

With regard to the disk of the planet, Encke, in his account of the discovery by Dr. Galle in Vol. xxv. (col. 52) of the *Astronomische Nachrichten*, writes: "Erlauben Sie mir nur hinzuzufügen, dass die Auffindung so schnell bloss durch die vortreffliche akademische Sternkarte von Bremiker möglich war. Eine Scheibe lässt sich erst erkennen, wenn man weiss dass es seyn wird." Bremiker's star-map, Hora xxi., was communicated to

the Berlin Academy on December 9, 1844, and it was lying for correction at the Berlin Observatory when Leverrier's letter was received (*Monthly Notices*, vol. xxxviii. p. 151).

Professor Challis published a second report to the Syndicate, dated March 22, 1847, relating to the subsequent observations of the new planet, but this need not be further referred to here, as it was reprinted in the *Astronomische Nachrichten* (vol. xxv., col. 309). The more Professor Challis's part in the history of the planet is examined, the more highly one appreciates his assiduity and zeal. He seems to have throughout done all in his power to encourage and assist Adams in his investigations, and it was through no fault of his that the honour of discovering a planet whose existence had been thus predicted does not belong to this country.

At the second return of Biela's comet since it was discovered to be periodic, in 1826, and the eleventh of its returns since it was first observed in 1772, it was found to have divided into two. It was observed by Encke on December 21, 1845, at Berlin, and by Valz, on December 25, at Marseilles; but no trace of separation was then noticed. In Europe the existence of two separate nuclei was first observed and announced by Professor Challis. In a letter to the President of the Society, printed in vol. vii. pp. 73, 74, of the *Monthly Notices*, he wrote:—"On the evening of January 15, when I first sat down to observe it, I said to my assistant, 'I see *two* comets.' However, on altering the focus of the eye-glass and letting in a little illumination, the smaller of the two comets appeared to resolve itself into a minute star, with some haze about it. I observed the comet that evening but a short time, being in a hurry to proceed to observations of the new planet [*Astræa*]. On first catching sight of it on this evening (Jan. 23), I again saw two comets. Clouds immediately after obscured the comet for half an hour. On resuming my observations I suspected at first that both comets had moved. This suspicion was afterwards confirmed: the two comets have moved in equal degree, retaining their relative positions. . . . . What can be the meaning of this? Are they two independent comets? or is it a binary comet? or does my glass tell a false story? I incline to the opinion that this is a binary or double comet, on account of my suspicion on Jan. 15. But I never heard of such a thing. I am anxious to know whether other observers have seen the same thing. . . . In the meanwhile I thought, with the evidence I have, I had better not delay giving you this information." In a subsequent letter he wrote:—"There are certainly two comets. . . . . I think it can scarcely be doubted, from the above observations, that the two comets are not only apparently, but really, near each other, and that they are physically connected. When I first saw the smaller on Jan. 15, it was faint, and might easily have been overlooked. *Now* it is a very conspicuous object, and a telescope of moderate power will readily exhibit the most singular phenomenon that has occurred for many years—a double

comet!" It appears that M. Wichmann, at Königsberg, observed the comet on the 14th, but saw nothing of the companion: there was, however, some vapour in the air. On January 15, the same night as that on which Professor Challis saw the two comets, the air being purer and the moon not risen, he saw the companion comet immediately with a power of 45. The duplication of the comet had, however, been previously observed at Washington by Lieutenant Maury, Director of the Naval Observatory, who "discovered during his observations on Jan. 13th a nebulous-looking object altogether cometary in its appearance, preceding Biela's comet by nine or ten seconds in the lower part of the field of view." On the 14th "both objects had increased about three minutes in Right Ascension since the night before" (*Monthly Notices*, vii. pp. 74, 90).

Professor Challis communicated his observations of the two heads of the comet to Adams, who calculated their orbits. The relative positions of the two heads formed the subject of Adams's first communication to the Society (March 13, 1846).

The comet at its return in 1852, when the distance between the nuclei was about eight times as much as before, was again observed by Professor Challis. Neither comet was seen in 1859 or 1866, and the remarkable circumstances relating to their supposed connection with the meteor shower of November 27, 1872, are too well known and too recent to need notice here (see *Monthly Notices*, vol. xxxiii.). Remarkable as the Cambridge observations of the Comet in January 1846 seemed to be at the time, its subsequent history has given even additional interest to them.

During the twenty-five years in which Professor Challis directed the Cambridge Observatory he was a very accurate and assiduous observer, making great use of the Northumberland Equatorial, and his contributions to the publications of the Society and to the *Astronomische Nachrichten* are very numerous. He also paid great attention to instrumental improvements, and to him is due the introduction in its present form of the collimating eyepiece, an instrument now so generally used that it is worth while to reproduce here the account he gives of it in his *Lectures on Astronomy* (p. 69):—

"This important auxiliary instrument, which enables the observer to obtain instrumental corrections exclusively by optical means, was the invention of Bohnenberger, of Tübingen, who has given a description of it in the *Astronomische Nachrichten* (Band iv., 1826, col. 327–336). My attention was first called to it by Henderson, late Astronomer Royal at the Cape of Good Hope, who brought me a specimen (made apparently according to the above-mentioned description), having a metallic reflector with a hole at the centre, through which the wires and their reflected images were looked at with a Ramsden Eyepiece. On trial I found this construction to be extremely inconvenient, on account of the limited field of view and the small interval between

the eye-glass and the wires, rendering it difficult to hold a lamp for throwing light upon the reflector. On mentioning these circumstances to the late William Simms, he constructed for me the instrument represented by Figs. 19 and 20, in which a three-glass eyepiece is substituted for the Ramsden Eyepiece, and for the metallic reflector a piece of plate-glass, the reflection from which, as will presently be explained, gives the means of seeing the wires, together with their reflected images, with quite sufficient distinctness. By these changes the above-stated inconveniences were entirely removed. As far as I am aware, the collimating eyepiece has since been uniformly made according to this pattern. I brought it into use in the Cambridge Observatory in the year 1850; the next year it was adopted at Greenwich when the new Transit Circle was first made use of. It had already attracted the attention of Bessel, Gauss, and Lamont, but had not, I believe, been definitively employed for exact determinations relating to meridian observations with the Transit instrument and Mural Circle before I made such application of it at the Cambridge Observatory."

He also invented the Transit-Reducer, a machine for calculating the formula

$$(a + b\cos z + \sin z)\frac{\operatorname{cosec}\delta}{15},$$

the total value of which is given by a single operation. The instrument which he used in the Cambridge Observatory was shown in the Great Exhibition of 1851, and received the award of a bronze medal. The machine is described in vol. x. of the *Monthly Notices*, and also on pp. 387–390 of his *Lectures*.

Another mechanical contrivance to which he devoted much attention was connected with his method of correcting the errors due to the forms of the pivots of a Transit instrument. The method which involved the use of the collimating eyepiece is described in vol. xix. of the *Memoirs*. Mention should also be made of the "Meteoroscope," an instrument invented by him for the purpose of rapidly determining the altitude and azimuth of any point of the heavens at which a meteor appeared. This instrument was a good deal used at Cambridge.

In the twenty-five years, 1836–61, during which Professor Challis was director of the Observatory, he published vols. ix.–xix. of the *Cambridge Observations*; vol. xx., which contained the observations for the years 1855–1860, was published by him in 1864, in accordance with the arrangement made when he retired from the directorship in 1861, by which he undertook the superintendence of the reduction and publication of the remainder of the observations made prior to 1861. On the Introductions to the different volumes of the *Cambridge Observations* he bestowed great pains and attention; the Introductions to those for 1836 and 1837 contain a detailed description of the methods of observing with the meridian instruments.

In the first years of his Professorship he lectured upon Hydrodynamics, Pneumatics, and Optics with special reference to the mathematical theories of Light and Sound; the leading facts were exhibited experimentally, and explanations were given of the principles employed in the mathematical reasoning. He published a Syllabus of these lectures in 1838. In 1843, when he had been director of the Observatory for seven years, he began a course of lectures on Astronomy and Astronomical Instruments, and this course he continued to give regularly, without interruption, until, as has already been stated, within the last few years. The Syllabus of these lectures, which he published in 1843, bears the title "A Syllabus of Lectures on Practical Astronomy and Astronomical Instruments: to which is added a list of Formulæ used in the Reduction of Astronomical Observations." Towards the close of his life he arranged his lectures in a form suitable for publication, and they were issued from the University Press at Cambridge in 1879, under the title "Lectures on Practical Astronomy and Astronomical Instruments." The volume contains 400 pages, and on every page of it there is evidence of the author's efforts to attain accuracy and his careful attention to *minutiæ* in all that concerns the instruments of an Observatory. It has special reference to the Cambridge instruments, and was intended mainly for use in the University; but he writes in the preface: "Although the instruments of the Cambridge Observatory and processes of observation I adopted in the use of them, have been more especially described, and the treatise consequently partakes somewhat of a local and personal character, I may venture, I think, to say that as having been written after twenty-five years of continuous labour in astronomical observations and calculations, and containing what may have occurred to me in the course of that experience as contributory to the advancement or improvement of practical astronomy, it will be found of some general utility as respects the work carried on in an Astronomical Observatory." All who attended Professor Challis's lectures will feel satisfaction that they are now placed on record. For nearly fifty years no one could have been more faithful than he was to the study of practical astronomy in the University.

Professor Challis wrote several papers on points connected with the integration of the equations in the Lunar Theory, which appeared in the *Philosophical Magazine* for 1854 and 1855, and a memoir on the Problem of Three Bodies, which was printed in the *Philosophical Transactions* for 1856. The first of the papers in the *Philosophical Magazine* (April 1854) was originally communicated to the Cambridge Philosophical Society, and was reported upon unfavourably by Professor Adams. In the number of the *Philosophical Magazine* for June 1854 Professor Challis invited Professor Adams to discuss with him its merits, and accordingly in the July number Professor Adams gave in detail the reasons for his disapproval of the new theorems contained in the paper. It is only fair to Professor Challis to men-

tion the handsome manner in which, fifteen years afterwards, in the introduction to his "Notes on the Principles of Pure and Applied Calculation," he acknowledges the justice of this criticism. He admits that the unfavourable report of the paper was made to the Council "not without reason; for it was a premature production, and had in it much that was insufficiently developed, or entirely erroneous. . . . . Theorem II. was wholly erroneous;" and he proceeds: "In my reply in the August number I said much in the heat of controversy that had better not have been said, and some things, also, that were untrue." He states further that when he found the discussion had not settled the matter, he pursued the inquiry in a series of communications, "which will at least attest the diligence with which I laboured to get at the truth of the question."

Before leaving the astronomical writings of Professor Challis, it is interesting to notice that the earliest of all his papers was astronomical, its object being to investigate an extension of Bode's law to the case of the satellites of the planets. It was read before the Cambridge Philosophical Society so long ago as December 8, 1828, and is printed in vol. iii. of their *Transactions*.

Professor Challis was the author of numerous papers on Hydrodynamics, Heat, Light, the Theory of Colours, &c. His Report on the State of Hydrodynamics—perhaps the best known of his mathematical papers—appeared in the British Association volume for 1833. It was in order to be enabled to devote more time to the development of his theories of mathematical physics that he resigned his charge of the Observatory. His "Notes on the Principles of Pure and Applied Calculation, and Applications of Mathematical Principles to Physics," is a large volume of 700 pages, which was published in 1869. He states that 112 pages were printed in 1859, when he was compelled to desist from it by the pressure of his occupations at the Observatory. After remarking that he holds it to be indisputable that physical science is incomplete till experimental inductions have been accounted for theoretically, and that the completion of a physical theory demands mathematical reasoning, he proceeds, "When according to the best judgment I could form respecting the applications which the results of my hydrodynamical researches were capable of, I seemed to see that no one was as well able as myself to undertake this necessary part in science, I gave up (in 1861) my position at the Observatory, under the conviction, which I expressed at the time, that I could do more for the honour of my University and the advancement of science by devoting myself to theoretical investigations than by continuing to take and reduce astronomical observations after having been thus occupied during twenty-five years. The publication of this work will enable the cultivators of science to judge whether in coming to this determination I acted wisely. Personally I have not for a moment regretted the course I took; for although it

has been attended with inconveniences arising from the sacrifice of income, I felt that what I could best do, and no one else seemed capable of undertaking, it was my duty to do. It should, farther, be stated that after quitting the Observatory, and before I entered upon my theoretical labours, I considered that I was under the obligation to complete the publication of the meridian observations taken during my superintendence of that institution. This work occupied me till the end of 1864, and thus it is only since the beginning of 1865 I have been able to give undivided attention to the composition of the present volume."

He subsequently published "An Essay on the Mathematical Principles of Physics with reference to the study of physical science by candidates for mathematical honours in the University of Cambridge" (108 pp., 1873), and "Remarks on the Cambridge Mathematical Studies and their relation to modern physical science" (93 pp., 1875).

Much that he wrote, especially on Hydrodynamics, did not receive acceptance from other mathematical physicists. He devoted his life with great assiduity and constancy to the search for philosophical truth, endeavouring to carry out Newton's principles. Although personally he was modest in the extreme, yet he was so earnest in his views and held such strong convictions as to the mode in which philosophical inquiries should be carried out that his language sometimes became almost self-assertive. In a letter to Whewell (1863) he wrote: "It has been the business of my life to endeavour to reach 'the second main series of physical discovery' in the direction that Newton indicated. Accordingly, I have adopted implicitly his 'foundation of all philosophy,' including therein his views expressed at the end of the *Principia* respecting the action of a 'very subtle spirit' (the ether) which 'pervades dense bodies,' and to the agency of which he attributes the phenomena of light, heat, electricity, &c. In conjunction with the Newtonian ideas I have taken advantage of the modern advancement in pure analysis, and in particular have applied partial differential equations in determining the motions and dynamical action of the supposed ether. It is marvellous how readily the results so obtained, taken in connection with the Newtonian properties of matter, adapt themselves to the solution of the great problems of Natural Philosophy. And yet none of my mathematical contemporaries have taken the same course, and I seem to remain the sole representative of the spirit of the Newtonian philosophy." He was so gentle in his character and his life was so simply and unselfishly devoted to the search after truth, that it is all the more matter for regret that the exceptional character of some of his views rendered part of his work of doubtful scientific value.

As Plumian Professor he was examiner for the Smith's Prizes, and he examined without intermission from 1836 to 1878. He set long papers, and he took great trouble over them. They form

a very remarkable series, and afford a perfect record of the matters that occupied his attention in all these years. Not only were the papers well suited to their purpose, but they possessed considerable interest of their own; and this is especially true, perhaps, of some of the earlier and simpler questions in each paper. The papers are to be found in the University Calendars for the different years; he had thoughts of reprinting them, in which case they would have formed an interesting and remarkable volume, but he abandoned the idea.

He was also author of the following works:—"Creation in Plan and in Progress: being an essay on the first chapter of Genesis" (1861); "A Translation of the Epistle of the Apostle Paul to the Romans, with an Introduction and Critical Notes" (1871); "An Essay on the Scriptural Doctrine of Immortality" (1880); "The Counting and Interpretation of the Apocalyptic 'number of the Beast'" (1881).

He was elected a Fellow of this Society on April 8, 1836, and of the Royal Society on June 9, 1848.

He leaves one son and one daughter. His son, Mr. James Law Challis, was appointed in 1860 to the Rectory of Papworth Everard, which had been held by his father from 1831 to 1852, and in 1878 he was presented by the Council of this Society to the Vicarage of Stone in Buckinghamshire, of which they were then the patrons. J. W. L. G.

Henry Dodgson, M.D., of Derwent House, Cockermouth, was born at Mockerkin, in Cumberland, on March 27, 1833, and was the youngest son of Isaac Dodgson, Esq. He chose the medical profession, and studied at the Universities of Edinburgh and Paris, graduating M.D. at Edinburgh in 1856. Since then he has practised in Cockermouth, and ultimately succeeded to one of the most extensive practices in the neighbourhood, where he was widely respected and esteemed. In 1866 he was proposed by the late Isaac Fletcher, F.R.S., M.P., and elected a Fellow of this Society. At that time he gave much of his time to observations in astronomy, and had an Observatory with a good telescope erected at considerable cost. But latterly, owing to the death of his partner and the calls of a large practice, he was obliged to relinquish a study he had a great love for. He, however, found time to be interested in the great educational movements of the day, and some years ago was elected Chairman of the School Board, which office he held up to the time of his death. He was a Fellow of the Meteorological Society, and took regular meteorological observations, which were published in the Registrar-General's reports. He died, after a fortnight's illness, of pneumonia, followed by typhoid fever. In 1866 he married his partner's niece (daughter of the late Edward Hughes, Esq., F.R.G.S., Head Master of the Royal Naval School, Greenwich) by whom he had nine children, who, with his widow, survive him.

Robert Charles May was born at Ampthill, in Bedfordshire, on April 5, 1829. His father, Mr. Charles May, F.R.S., was a partner in the firm of Ransomes & May, of Ipswich, and it was in the works of that well-known engineering firm that Mr. Robert May served his apprenticeship; after which time he held the post of out-door manager, a position that gave him great experience as a mechanical engineer in the erection of steam mill-machinery, as well as in that of fixed plant on railways, such as iron aqueducts, roofs, bridges, &c. Afterwards he had charge of the works other than rolling stock on the South Eastern Railway. Leaving this position in 1852, he was associated with the late Mr. J. M. Rendel, F.R.S., in some of the hydraulic works of that eminent engineer. He constructed, in 1853, the outfall of the Walland and Denge marshes at Jury's Gut, or Jew's Gap, in Kent, and placed there a reservoir or tidal pen, at the sea end of which were draw-gates, and at the land end self-acting tidal doors. The tidal water was thus penned in, and formed a sufficient scour to keep the outfall clear of the shingle and sand which travel from west to east with the tide on that coast. In 1854, about three years after his father had left Ipswich and settled in London as a consulting engineer, he followed his father's example, and soon acquired a very considerable practice in gas, mill, and railway engineering, and was largely employed as superintendent engineer in the construction of fixed and moving railway plant for home and foreign railways.

As an arbitrator in engineering disputes he had a very large experience, and was almost without a rival, for he put his whole heart into whatever he undertook, and brought sound mechanical knowledge of a high order, with an exceptionally clear and analytical judgment, to bear upon the questions with which he had to deal. His high integrity and fairness commanded the esteem of both sides, and gave considerable weight to his decisions. He had also a very large experience in valuation work.

In his later years he devoted some attention to mining work, and in the last two or three years of his life he held the appointment of consulting engineer to the Gallizzi Sulphur Mines in Sicily, and he was lately appointed to a similar position in the Giona mines in the same island. These appointments necessitated his travelling to the Mediterranean twice a year, and it was on his return from Sicily, and immediately on his arrival at his hotel at Marseilles, that he was seized with the illness (aneurism of the heart) which in a few minutes terminated his life, on July 20, 1882.

He was a Member of the Institution of Civil Engineers, and an old Member of the Institution of Mechanical Engineers. He was also also one of the Assessors of the Board of Trade. He was elected a Fellow of the Society on May 10, 1861.

Edward Hamilton Pringle, the fifth son of the late Mark Pringle, formerly of Oakendean, Karsham, and J.P. and D.L. for

Sussex, was born January 1, 1844, at Oakendean. He was educated chiefly at the Edinburgh Academy and Edinburgh Military Academy. In 1864 he went out to Queensland, and was engaged in sheep-farming in that colony for two years. He then proceeded to India, where Lord Napier of Ettrick, at that time Governor of Madras, conferred on him the appointment of Assistant Engineer in the Public Works department. After holding successively the posts of Special Executive Engineer of Wainád, District Engineer of South Kanara, and Divisional Officer of the West Coast, he was gazetted to Gaujám; and at Berhampúr, in that district, he was seized with cholera on May 30, 1882, and expired after a few hours' illness.

He was devoted to scientific pursuits from his boyhood, and, in addition to his astronomical attainments, was an acute and careful naturalist. He applied himself chiefly to spectral astronomy, but was unfortunate in being long stationed on the hills of Malabar, which for months together are enveloped in clouds and mist, and are otherwise unsuited for observations save at rare intervals. His health was moreover much shattered by fever contracted in the jungles of Wainád, and of late years the pressure of official duties allowed him scant time for the pursuit of his favourite science.

Mr. Pringle was a not unfrequent contributor to the pages of *Nature* on astronomical and zoological questions, and in 1877 published a small pamphlet on the subject of forests in relation to famines, a matter which has since then engaged much attention in India.

He was elected a Fellow of the Royal Astronomical Society on April 10, 1874; he was also a Fellow of the Royal Geographical Society and a Member of the Society of Telegraph Engineers.

Thomas Romney Robinson, D.D., F.R.S., was born in Dublin on April 23, 1792. His abilities and genius seem to have been manifested at a very early age, and his first appearance as an author dates so far back as 1806. On that occasion his venture was entitled "Juvenile Poems by Thomas Romney Robinson, to which is prefixed a short account of the Author by a Member of the Belfast Literary Society": Belfast, 1806. The book contains a number of poems written by the author at various ages below thirteen. Dr. Robinson's last publication is in the *Philosophical Transactions* for 1880, and it must be regarded as a curious circumstance in literary history that an interval of three-quarters of a century should have elapsed between Dr. Robinson's first appearance as an author and his last.

In the year 1814 Dr. Robinson was elected a Fellow of Trinity College, Dublin, and he was for several years engaged in lecturing in the University as Deputy Professor of Natural Philosophy. In connection with his labours as a teacher he

published in 1820 a volume entitled *A System of Mechanics for the Use of Students in the Dublin University.*

After a residence for nine years at Dublin University, Dr. Robinson accepted the living of Enniskillen, which was in the gift of Trinity College. Robinson's career in the University was thus finished the year before Humphrey Lloyd, the late Provost, was elected to a fellowship. Dr. Robinson did not long remain Rector of Enniskillen. In the year 1824 he exchanged the living of Enniskillen for that of Carrickmacross; and of his ecclesiastical career there is little further to note, except that about half a century later (in the year 1872) he was nominated a Prebendary of St. Patrick's Cathedral, Dublin, and that several of his sermons have been published.

Dr. Robinson is principally known to fame by his connection with the Armagh Observatory. The Observatory at Armagh was founded in 1793 by Primate Robinson. The endowment of the Observatory, as well as that of a public library, arose out of Primate Robinson's scheme of forming at Armagh a university which might serve for the education of the North of Ireland. It is needless to say that the greater part of the Primate's beneficent scheme was never realised. At his death the meridian instruments he had ordered for the Observatory seem to have been countermanded by his heirs. The two following Primates had but little interest in science, and it was not until they were succeeded by Lord John George Beresford, the late Primate, that any further steps were taken. Primate Beresford presented to the Observatory a Transit Instrument, a Mural Circle, and an Equatorial Reflector of fifteen inches aperture. The first of these was erected in 1827, and the last in 1835. It was in the year 1824 that Dr. Robinson was appointed Director of the Armagh Observatory. He threw himself into the work of practical astronomy with the greatest zeal and success, and the celebrated Armagh Catalogue is a noble monument of his assiduity and skill. This catalogue, though not published until 1859, contains many observations of stars between the years 1830–40, of which we possess few contemporary observations. On this account the Armagh Catalogue has a distinct value, and it has been much used by Argelander in his investigations of the proper motion of 250 stars in vol. vii. of the Bonn Observations. It may be mentioned that a note by Dr. Robinson giving the places of three stars, which were affected with errors in the Armagh Catalogue, appeared in the *Monthly Notices* as recently as last March; it was read at the meeting at which his death was announced. The Mural Circle at Armagh was subsequently furnished with a new telescope having an objective of seven inches aperture, and with this 1000 of Lalande's stars, nearly all between 6·0 and 7·5 magnitude, were re-observed in 1868-76, and the results have been published in the *Transactions* of the Royal Dublin Society, new series, vol. i.

Dr Robinson's determination of the Constant of Nutation also

deserves notice, though, for reasons which need not now be discussed, it has never come into practical use among astronomers.

The celebrated cup anemometers, now so extensively used, are an indication of the practical skill and ingenuity by which Dr. Robinson was distinguished. The very latest scientific labour of his long life was a redetermination of the constants of the cup anemometer. This was accomplished by experiments on a very large scale, in the dome of Mr. Grubb's workshops, at Dublin. The results of these labours have been published in the *Phil. Trans.*, 1878–1880.

Considering that Dr. Robinson was an author before the battle of Trafalgar, that he was elected a Fellow of Trinity College, Dublin, before the battle of Waterloo, and that he was made Director of the Armagh Observatory within a year or two of the death of Sir W. Herschel, it is not surprising to find that his scientific friends and associates belonged mainly to the past generation. In that past generation, Dr. Robinson occupied a distinguished and remarkable position. He was intimately associated with the late Earl of Rosse in all those memorable experiments which culminated in the great Reflector at Parsonstown. He was the friend of Sir James South, of Sir William Fairbairn, and of many other celebrities. His wide sympathy, his gentle and invariable kindness, his wondrous stores of knowledge, his charming powers of conversation, his brilliant eloquence, were qualities universally recognised, and caused him to be welcomed and beloved in many circles besides those purely scientific.

He was elected a Fellow of the Society on May 14, 1830.

R. S. B.

Charles Vincent Walker died at his residence at Tunbridge Wells, on the morning of December 24, 1882, in the seventy-first year of his age. He had been Telegraph Engineer to the South Eastern Railway since 1845, and was one of the oldest telegraph engineers in the country. He was a zealous worker in the science of electricity, and was the inventor of several useful appliances in connection with telegraphy, including the instruments by which the block system on railways is worked. His name is especially associated with the origin of the distribution of time by telegraph. On May 10, 1849, Mr. Glaisher wrote to Mr. Walker that he wished to talk with the latter about the laying down of a wire from the Observatory to the Lewisham Station, and on May 23 following, the Astronomer Royal gave Mr. Walker a brief sketch of the use to be made of the wire referred to, his scheme, as he stated, being "the transmission of time by galvanic signal to every part of the kingdom in which there is a galvanic telegraph from London." It was proposed to lay four wires underground from the Royal Observatory to the railway station at Lewisham, and to extend them to London Bridge. The South Eastern Railway Company gave every

facility. On September 16, 1852, an electric clock at London Bridge Station was erected, and connected by wire with an electric clock at the Royal Observatory, Greenwich. The first time-signal sent from the Royal Observatory was received at London Bridge Station at 4 p.m. on August 5, 1852; and on August 9, 1852, Dover received a time-signal for the first time from the Royal Observatory direct, and it was made visible at certain first-class stations between London and Dover. After that the system rapidly spread, its success depending greatly on the scientific skill and zeal of Mr. Walker.

He was elected a Fellow of the Royal Society in 1855, and he was a late President of the Meteorological Society, and of the Society of Telegraph Engineers. He was elected a Fellow of the Society on January 8, 1858.

Emile Plantamour.—In the Annual Report of last year the death of Gautier was announced, and now we have to record the death of his pupil and successor as Professor of Astronomy and Director of the University at Geneva, which occurred on September 7, 1882. Plantamour was born at Geneva in 1815. He received his early education in the old college, founded by Calvin, after which he spent eight years in the then celebrated school of Hofroyl. In 1833 he entered the Geneva Academy, where he became one of Gautier's most promising pupils. After graduating in philosophy, he resolved to make the study of astronomy the work of his life, a design in which he was encouraged by Gautier, who promised to vacate his chair in Plantamour's favour when the latter had completed his university education. The chief reason—an affection of the sight—which caused Gautier to desire to retire from the direction of the Observatory was referred to in the obituary notice of Gautier. From Geneva Plantamour proceeded to Paris, where he studied for two years under Arago. He also was a pupil of Bessel at Königsberg, where, in 1839, he took the degree of doctor, the subject of his thesis being the methods of calculating the orbits of comets. From Königsberg he went to Berlin, and worked for some time with Encke, who recognised in his quickness of observation and aptitude for complex calculations his special fitness for the career to which he intended to devote himself. On his return to Geneva Plantamour received the double appointments of the professorship of Astronomy in the Academy, which has since been transformed into a University, and director of the Observatory. In 1848 he accepted also the chair of Physical Geography, and he retained all three positions until his health began to fail him a few months before his death. His publications chiefly related to atmospheric electricity, observations of comets, and meteorological observations made on the Great St. Bernard. Special reference should be made to the important investigations of the diurnal oscillations of the soil undertaken by him by means of spirit levels, and of which accounts are given in the *Comptes Rendus* for 1878

and 1879. Much of his time was devoted to meteorology, and his papers in the *Bibliothèque Universelle* on the subject were numerous; he was also one of the most active members of the Helvetic Scientific Society for the observation of atmospheric phenomena. He devoted attention to Geodesy, and in 1861 became the representative of Geneva on the Paris Geodetic Commission. He was also a useful member of the International Geodetic Association which met a few years ago at Geneva. In connection with the Genevan Society of Arts he organised a watch and chronometer competition, which has proved of great value to the staple industry of Geneva. Watches and chronometers are sent to the Observatory and tested there, the results being published, and prizes awarded to the best timekeepers. Four years ago he added to the observatory at his own expense a refractor of ten inches aperture, and he erected the building for its reception. He was a man of fortune, and might have devoted his life to social enjoyment and ease; but he was deeply attached to science, and preferred to retain his posts in the University, although the modest salary he received scarcely covered his expenses.

He was an honorary member of the Turin Academy, and a correspondent of the French Institute. He was elected an Associate of the Society on April 12, 1844.

Johann Karl Friedrich Zöllner was born at Leipzig on November 8, 1834, and died on April 25, 1882. In 1872 he was appointed Professor of Physical Astronomy in the University of Leipzig. He was the author of numerous papers in the *Berichte* of the Saxon Academy of Sciences, on subjects connected with Spectrum Analysis and the constitution of the Sun, and also of several larger works, the most important of which was published in 1865 under the title *Photometrische Untersuchungen*. Upon the same subject he also published his *Grundzüge zu einer allgemeinen Photometrie des Himmels*. His researches on the philosophy of space, and other subjects, with his theories of light and electricity, appeared in the three volumes of his *Wissenschaftliche Abhandlungen*. In 1872 he published his work *Ueber die Natur der Cometen*, upon a third edition of which he was engaged at the time of his death. He was the inventor of several appliances for spectroscopic and photometric researches. He was elected an Associate of the Society on November 8, 1872.

Proceedings of Observatories.

The following Reports of the proceedings of Observatories during the past year have been received by the Council from the Directors of the several Observatories.

Royal Observatory, Greenwich.

The general meridian work at the Royal Observatory during the past year has gone on with the same regularity as in former years, special attention having been given to the observation of the Moon on every favourable opportunity throughout the lunation, and to the Sun, planets, and fundamental stars when they have passed the meridian before 15^h. The larger minor planets have also been observed about the time of opposition, when practicable. The Working Catalogue of 2600 stars, alluded to in former Reports, including all stars down to the fifth magnitude, and others required for various purposes, is now nearly cleared off, and a new Working Catalogue is in preparation, including all the stars down to the sixth magnitude contained in Dr. Heis's *Atlas Coelestis*, which had not been previously observed at Greenwich with the Transit Circle. Comet *a* 1882 (Wells) has been observed twelve times on the meridian *sub polo*, and Comet *b* 1882 (the Great Comet) three times.

The mean error of the Moon's tabular R.A., from observation with the Transit Circle in 1882, is $+0^s.82$.

Two new determinations of the flexure of the Transit Circle were made in 1882, on January 2 and December 30, the resulting values being respectively $+0''.03$ and $-0''.07$. No correction for flexure, as determined by the collimators, has been applied to the observations.

In order to extend the range of the reflexion observations of stars, which, owing to the interference of the two collimators, had been hitherto limited to within an arc of 40° from the zenith, and thus to obtain data for determining the true law of the R−D discordance, a new arrangement of the mounting of the collimators was carried out in the summer of 1882, in which the collimators are mounted on upright arms turning about centres below. This allows them to be swung on one side when not in use, the piers being cut away so as to offer no obstruction to reflexion observations as far as Z.D. 71° on each side of the zenith. The importance of this extended range of reflexion observations is shown from an examination of the mean discordances of (R−D), which, for last year, steadily increase from

the zenith to Z.D. 70°, at which point the discordance between direct and reflexion observations amounts to 1″·6.

Notwithstanding this fundamental change in the mounting of the collimators, their stability from day to day is found not to be sensibly affected; but, as a matter of precaution, it is usual to place the corresponding wires of the north and south collimators in coincidence immediately before and after each determination of the collimation error of the Transit Circle. There is rarely any sensible difference between the two sets of readings.

With the Altazimuth the Moon has been observed at every practicable opportunity, on the same system as in former years, to the end of the lunation on 1882, July 9. Since this date the observations have been restricted to the first and last Quarters of each lunation, as it has been shown by a comparison of the number of observations made with the Transit Circle and Altazimuth, that the intermediate semi-lunation, before and after Full Moon, is well represented for all practical purposes by the daily observations made on the meridian. Advantage has been taken of this arrangement to devote greater attention to the observation of comets and other miscellaneous phenomena with the Equatorials, &c. In order to adopt the Altazimuth to the observation of comets, a new system of wires, having central cross wires thicker than the others, was inserted at the beginning of the present year.

Comet *a* 1882 (Wells) was observed on five days with the Naylor Equatorial, Comet *b* 1882 (the Great Comet) on eight days with the Sheepshanks Equatorial, and Comet *c* 1882 (Barnard) on one day with the S.E. Equatorial. Comet *b* was also observed on one day with the Altazimuth. The resulting apparent R.A. and N.P.D., together with the mean places of the comparison stars, are published in the *Monthly Notices* for November. Micrometric measures of the positions of six of the satellites of *Saturn*—*Enceladus*, *Tethys*, *Dione*, *Rhea*, *Titan*, and *Iapetus*—have also been made on several evenings with the S.E. and Sheepshanks Equatorials.

Twelve occultations of stars by the Moon have been observed in 1882, and also eighteen phenomena of *Jupiter's* satellites.

The solar eclipse of May 16 was favourably observed with the S.E. Equatorial, and four series of differences of R.A. and N.P.D. of the cusps and limbs were obtained. The plan of observation was so arranged as to give corrections to the tabular R.A. and N.P.D. of the Moon, and to the adopted semi-diameters of the Sun and Moon. During the eclipse, which at its greatest phase only covered 0·186 of the Sun's disk, eighteen differences of R.A. of cusps, ten differences of N.P.D. of limbs, and nine differences of N.P.D. of cusps, were observed. The times of the beginning and ending of the eclipse were also recorded by several observers.

The spectroscopic observations have been made as usual

with the "half-prism" spectroscope mounted on the S.E. Equatorial. The routine observations have been less numerous than usual, partly owing to the cloudy weather of the latter half of the year, and partly to the pressure on the Photographic department from the increase in the number and size of the Sun-spots as the period of maximum solar activity is approached. The spectra of various Sun-spots have been examined on ten days; the great Sun-spot of November last being especially remarkable for the instances of reversal of lines which it displayed. The examination of the chromosphere for prominences has been made on twenty-two days, and numerous prominences were seen on each occasion.

The displacement of the F or *b* lines has been measured in the spectra of thirty-one stars. This work has suffered some interruption during the period of observation of Comets *a* and *b*, the former of which was examined with the spectroscope on eight occasions, and the latter on three. The single-prism spectroscope has also been employed on one night for the measurement of the positions of the bands in the spectrum of *Uranus*, and the "experimental half-prism" spectroscope was employed on the night of November 17 in the examination of the spectrum of the Aurora. All the spectroscopic observations have been completely reduced to the end of 1882.

Photographs of the Sun have been obtained with the photoheliograph on 201 days during the year; whilst in 1881 they were taken on 173 days. This increase is due to arrangements having been made for securing photographs on Sundays. The increased number of photographs, and, still more, the remarkable increase in the number and size of the Sun-spots, have rendered the work of their measurement and reduction much more severe than in previous years. The reductions have, however, been considerably lightened, without any real loss of accuracy, by limiting the calculations to tenths of a degree instead of to minutes. The photographs have been measured in duplicate to the end of 1882, and completely reduced to 1882 October 8.

Arrangements have been made with the Solar Physics Committee by which the gaps in the Greenwich series of Sun-pictures will be filled up as far as possible by photographs taken at Dehra Dûn (India) and elsewhere, thus rendering the series practically continuous. Seventy-nine photographs dating from 1881 December 22, to 1882 June 30, have already been received from the Committee and of these thirty-six, up to 1882 March 8, have been measured in duplicate, and twenty-eight, up to 1882 February 20, have been completely reduced.

The reductions of the observations in every department are in a forward state, and the complete copy of the observational sections of the volume of *Greenwich Observations* for 1882 will shortly be ready for the printer. The printing of the *Greenwich Observations* for 1881 is nearly finished, the whole of the volume being in type, and it is hoped that it will be ready for distribu-

tion in the spring. The separate copies of the Results of the Spectroscopic and Photographic Observations for 1881 have been already distributed in advance of the volume.

Armagh Observatory.

By the Act of Parliament (Irish Statutes, 31 George III., ch. 46) "for settling and preserving a Public Observatory in the city of Armagh," the appointment of the Astronomer is vested in the Archbishop of Armagh, while the Observatory is under the control of a Board of Governors and Guardians, of whom the Primate is Chairman.

On February 28, 1882, the Rev. T. R. Robinson died, after having had charge of the Observatory for more than fifty-eight years. In June the Primate appointed Dr. J. L. E. Dreyer to succeed Dr. Robinson; but as extensive repairs to the dwelling-house were necessary, Dr. Dreyer did not take up his residence at the Armagh Observatory till August 31.

The principal instruments now in use are:—

1. A Mural Circle by Jones, with a telescope of seven inches aperture by T. Grubb, and two collimators.

2. A Chronograph by Knoblich (clock movement improved by Grubb).

3. A 15-inch Reflector by T. Grubb, mounted equatorially with clockwork; can be used either in the Newtonian or the Cassegrain form.

4. A 3·8-inch Refractor by Jones, on a portable Equatorial Stand.

5. Three Sidereal Clocks (one with barometer compensation); one Mean Time Clock.

The Transit Instrument, with which the R.A.'s of the Armagh Catalogue were determined, has not been in use for the last twenty years, but is in good order. A 12-feet Zenith Sector (formerly at Kew) has lately been dismounted. Besides several minor instruments (a sextant, two theodolites, &c.), there are a number of old instruments which now only possess historical interest.

Since 1864 the Mural Circle has been employed to determine the places of a number of stars from Lalande-Baily's Catalogue. Close upon 3,000 stars have been observed, most of them from three to five times. These are now being prepared for publication as a second Armagh Catalogue, for 1875, a grant having been obtained from the Royal Society for the purpose of printing this.

With the Reflector the ingress of *Venus* on the Sun's disk was successfully observed (see *Copernicus*, January 1883). If the steps which are now being taken to procure for the Observatory an Equatorial Refractor should prove successful, it is

intended to devote this instrument to micrometrical work, and probably to try Cluster Photography with the Reflector.

The self-recording meteorological instruments established in 1868 have been working without interruption.

By order of the Board of Governors a history of the Observatory has been drawn up, and is now about to be printed in pamphlet form.

Cambridge Observatory.

As in former years, our attention has been specially given to the Zone observations with the Transit Circle, and the reductions have been carried on with great assiduity. The True Right Ascensions and the True North Polar Distances are calculated up to the end of 1881, and Tables are in course of preparation, not only for reducing the places to the Mean Equinox at the beginning of each year, but also for again reducing these results to 1875·0, which is the epoch chosen by the German Astronomische Gesellschaft.

These observations have, however, on several occasions been interrupted by the fine comets which have recently attracted so much attention.

Comet *Wells*, 1882, was observed on twenty-four nights, from April 5 to May 31 inclusive, with the Northumberland Equatorial and Square Bar Micrometer, and fourteen times with the Transit Circle: and a very satisfactory parabolic orbit was obtained by Mr. Graham from the observations of April 5, 14, and 22.

The Great Comet 1882 (*b*) was compared 159 times with neighbouring stars from October 25 to December 6 inclusive.

All these observations have been reduced and communicated to the Royal Astronomical Society, with the exception of the fourteen meridian observations of the Comet *Wells*.

The bad weather entirely prevented any observation of the Transit of *Venus* being made at this Observatory.

Dunsink Observatory.

During the past year there has been a change here, owing to the appointment of Dr. J. L. E. Dreyer, to succeed the late Dr. Robinson at Armagh. The vacancy thus made has been filled by the appointment of Mr. Arthur A. Rambaut, of Trinity College, Dublin.

The Chronograph is now in good working order, and meridian observations of the selected list of stars are in progress (see Report last year). The Equatorial has, as before, been chiefly employed in researches on Annual Parallax. The series for Σ 2486=6 β *Cygni* has been completed and discussed, and the

result shows that this star has a parallax of $0''{\cdot}482 \pm 0''{\cdot}054$. The series of observations on μ *Cephei* has been finished, but the results are not yet ready for publication.

During the autumn, observations of *Victoria* and of *Sappho* were made in conjunction with those simultaneously made by Mr. Gill at the Cape for the determination of the Solar Parallax.

The Transit of *Venus* was seen to some extent. Clouds obscured the contacts, but micrometrical measures of the distances of the limbs were obtained.

Part IV. of our publications was distributed last year. Part V. has gone to the press. It will contain a detailed account of the Parallax work with the Equatorial.

Royal Observatory, Edinburgh.

The work of daily time-signals, by both ball, gun, and controlled clocks, with the necessary observations, have been carried on as usual through the past year; likewise the calculations of the bi-diurnal meteorological observations at 55 of the stations of the Scottish Meteorological Society, for the Registrar General of Scotland, and have been printed in his monthly and quarterly returns.

In the course of last July the Government made a grant of money towards binding the many unbound pamphlets belonging to the Observatory; and assured the Astronomer that they had the resumption of printing the Star Catalogue and the repair and completion of the instruments, as recommended by their Commissioners of Inquiry in 1876 and 1879, under their serious consideration.

Glasgow Observatory.

Apart from the ordinary operations connected with the transmission of Greenwich Mean Time to the city and port of Glasgow, there is only to report, in connection with the past year, the final passing through the press of the Glasgow Star Catalogue, which is expected to be ready for distribution in two or three weeks. The Glasgow Observatory was one of the few favoured places in the British Isles where an observation of the ingress of *Venus* on the Sun's disk was obtained on the 6th of December, 1882.

Kew Observatory.

Sun-spot observations on Hofrath Schwabe's method have been made on 197 days. The Sun's surface was found to be free from spots on three of those days.

A small portable $2\frac{3}{4}$-inch refracting telescope, with a magnifying power of 42 diameters, was used by the observer till July 3; since that date the observations have been made by means of the Photoheliograph, which was removed from the Loan Collection at South Kensington for that purpose, and reinstated on the pedestal in the Dome, a position which it occupied prior to its being sent to the Royal Observatory, Greenwich, in 1873.

The spots are now drawn by the observer, as they appear projected upon the focussing screen.

The measurements and reductions of Sun-spot positions and areas, as determined by means of the Kew Photoheliograph, from 1864 to 1872, having been completed for Mr. De La Rue, he has deposited the manuscript with the Council of the Royal Society.

Preparations were made with a view to obtain photographs of the Transit of *Venus*, but clouds prevented any being taken.

The usual magnetical and meteorological observations and reductions have been carried on as formerly.

Liverpool Observatory, Bidston, Birkenhead.

During the past ten years between two and three thousand chronometers have been tested at this observatory in three definite temperatures. The temperature is changed fifteen degrees at the end of each week in the following order: 55°, 70°, 85°, 70°, 55°. The object of changing the temperature in this way is to show the amount of variation in the rate due to change of temperature apart from the change of rate arising from other causes, and in this way to obtain the data necessary for calculating the corrections to the rates due to change of temperature by the formulæ published in the Report on this Observatory for 1872. The thermal factor ranges in different chronometers from about 0·001 to 0·004, the average being 0·0025. With this factor, when the maximum gaining rate is at 70°, the change of rate due to change of temperature between 40° and 100° is $2^{s}\cdot5$ a day; but if the temperature of maximum gaining rate should be 30° on either side, 70° the change of rate between 40° and 100° amounts to $9^{s}\cdot0$ a day. There is no difficulty in correcting the rates for error of thermal adjustment, and the change of rate arising from other causes can be detected and allowed for at sea by daily comparisons of the chronometers with each other, and by occasional observations of well-known points of land.

There are now deposited at this Observatory the records of upwards of one hundred voyages from Liverpool to and from the west coast of South America. Each ship carried three chronometers, and the Greenwich time, carried on by rates corrected for change of temperature, has been recorded daily

throughout each voyage. Numerous observations have also been made by the officers of the Pacific Steam Navigation Company for checking the chronometers at intervals during the voyage. The results show that by keeping such records it is practicable to render chronometric navigation sensibly perfect.

The meteorological observations obtained from the self-recording instruments have been tabulated, and telegrams have been sent daily to the Meteorological Office and to the Liverpool Underwriters' rooms.

Radcliffe Observatory, Oxford.

Observations have been systematically made with the Transit Circle throughout the year 1882.

The number of observations is as follows:—

Transits	2117
Circle Observations (each requiring the reading of the four microscopes)	2189

These totals include—

	In R.A.	In N.P.D.
Observations of Sun at Solstices and Equinoxes	32	29
Observations of Moon	54	56
Comet *a*, 1882	15	16
Reflexion Observations of Stars ...	—	109

and

162 pairs of Nadir Observations.

No opportunity was afforded of observing the time of passage of the Moon's diameter during the year, but 17 measures of the vertical diameter have been secured.

Two new wires were inserted by Mr. Simms on Oct. 2, and the equatorial intervals of the whole system have been carefully redetermined. An investigation of the flexure of the telescope has recently been made. The value found was almost identical with that which has been in use since 1880, June.

The current reductions are in a forward state, the N.P.D.'s being completely, and the R.A.'s very nearly, reduced up to date.

The Astronomical Results for 1880 have been printed.

The observations for 1881 have been discussed, and are being prepared for press. Following the plan adopted at the Cape, the Nadir Points have been exclusively determined with the Nadir reflecting eyepiece; but frequent observations of stars by reflexion, north and south of the zenith, have been made as a check upon the existence of any systematic errors.

From 27 Northern stars with 56 reflexion observations and 57 direct observations the value of R—D is

$$-0''.222;$$

whilst from 34 Southern stars with 77 reflexion observations and 108 direct observations the value of R—D is

$$+0''.013.$$

The mean discordance between the Nadir Points determined from the wire observations and from the star is therefore only

$$-0''.08.$$

The colatitude found from observations made during the year 1881 is

$$38^{\circ}\ 14'\ 25''.05;$$

but if the Nadir Points used had been those deduced from reflexion observations of stars alone, the colatitude would be

$$38^{\circ}\ 14'\ 24''.95.$$

The difference between these results is small, and the uncertainty of the colatitude determination of the year is therefore confined within very small limits.

A series of Northern stars which have been used in the determination of differences between the longitudes of the Cape Observatory and Aden have been under observation here at the request of Mr. Gill.

Seventeen observations of phenomena of *Jupiter's* satellites, seven of occultations of stars by the Moon, and the eclipse of the Sun on May 16 have been made with the extra-meridional instruments.

The Meteorological Results for 1880 have been printed and distributed, and those for 1881 are being discussed.

In addition to the regular work of the Observatory the grounds have been made available for the erection and trial of the instruments of the different Transit of *Venus* expeditions which were sent from this country, and for a comparison of the clock errors of the different observers with those of the Standard Sidereal Clock as determined by the Observatory staff.

The sky was clouded here generally during the time of the Transit, but a view of *Venus* well on the Sun was obtained during a short break in the clouds.

Oxford University Observatory.

The whole strength of the Observatory has been, without intermission, directed to the photometry of the brighter stars from the Pole to the Equator, including a few stars of inferior brightness, or of southern declination, but possessing interest. This work was substantially completed in December last; a few stars remaining for re-observation. Professor Pritchard has taken one of the two telescopes, and its photometer used for the above purpose, to Cairo, in order to complete the Memoir, in respect of the atmospheric and climatic effects on the apparent brilliancy of stars. The more interesting results of the general photometric work have been communicated to the Society during the past year.

In the *Memoirs* of the Society will be found a communication on the Photographic Diameter of the Moon, which, it is believed, establishes the applicability of photography to astronomical measurements of the most delicate character. There still remains in the Observatory a research, all but ready to be submitted to the Society, on the relative positions of the brighter stars in the group of the *Pleiades* observed with the Duplex Micrometer.

Arrangements were made for the observation of the Transit of *Venus* by several observers with telescopes of various apertures, but unfortunately without avail, owing to unfavourable weather. Notwithstanding the unpromising nature of the day, some fifty members of the University assembled at the Observatory, remaining there until sunset in patient hope of at least a glimpse of the planet on the Sun, which would have been exhibited after the manner of Horrox's historical method of projection.

It is right to acknowledge the continuance of the very cordial assistance of the Board of Visitors, and the zealous aid of the assistants, Mr. W. E. Plummer and Mr. Jenkins. The latter accompanies Professor Pritchard to Cairo; the former is left in charge of the Observatory during his absence.

Stonyhurst College Observatory.

During the past year the entire chromosphere has been measured on 70 different days. Two hundred and twenty-one drawings of the solar spots have been made in the usual manner, and several enlarged drawings of the more remarkable spots and groups have been made to a scale of 30 inches to the solar diameter.

The observations of *Jupiter's* satellites, and of occultations of stars by the Moon, have been continued as in previous years.

Owing to the badness of the weather, the position of Comet

b, 1882, was observed only a few times with the 8-inch Equatorial. Four transits of the comet across the meridian were observed.

The solar eclipse of May 16 was well observed both with the spectroscope and telescope.

Temple Observatory, Rugby.

The measurement of position and distance of double and multiple stars has been continued as usual during the past year, and 255 complete sets of measures of 105 stars have been made, so that each star has been measured on either two or three different nights.

The Observatory has been open on 77 nights, but in this are included a few cloudy ones, when opportunity was taken to go through the finding of instrumental errors with the most advanced boys.

Some attention has been given to the measurement of recession and approach of stars with the spectroscope on the Reflector, and the comet was observed several times, and drawings were made of it.

Mr. Percy Smith made some excellent drawings of the large Sun-spots in November.

Mr. Barclay's Observatory, Leyton, Essex.

The ordinary routine work has been carried on as usual. Measures of double stars and observations of planetary satellites have been made.

Mr. Talmage left, in October 1882, for Barbadoes, to observe the Transit of *Venus*, and will not return till the middle of February. During his absence only some meteorological work is carried on.

Mr. Campbell's Observatory, Arkley, Barnet.

The observations of the Moon are still continued at this Observatory, with a view to the determination of the distance of the Sun by means of the parallactic inequality.

This year's work has been much interrupted by an accident and by absence from home.

The analytical part is in a forward condition, as applied to the 134 observations taken before the end of 1882, and will, it is hoped, be still carried on by Mr. Neison.

Mr. Common's Observatory, Ealing.

During the past year the three-foot telescope has been chiefly used for photography.

The great difficulty of commanding a long exposure has been well got over by a special arrangement that gives an exposure for any desired time with small deviation from accuracy in following the image. It is quite probable that details in the fainter parts of nebulæ may now be photographed that would not be detected by eye-observation.

With this arrangement for exposing the plate, photographs of the great nebula in *Orion* have been taken, which in extent and amount of detail exceed expectations founded on the results of previous attempts.

On September 16, at $22^h\ 45^m$, a comet was found near the Sun with the helioscope erected in 1881. This proved to be the Great Comet of 1882, near perihelion. Photographs of the remarkable nucleus were obtained in the month of November, and a number of sketches made with the three-foot telescope.

Colonel Cooper's Observatory, Markree.

With the large Refractor the measures of double stars and of the diameters of planets were continued during the year. The Transit of *Venus* and other phenomena were observed.

The observations with the Meridian Circle were discontinued pending the construction of a new Standard Clock to mark the Chronograph. It was found that too much time was lost in signalling from the Sidereal Clock in the meridian-room, which was necessary on account of the badness of the clock that marked the prickers on the Chronograph.

The meteorological registers have been kept, as heretofore, by an assistant. They are the most complete registers in this country, with the exception of those obtained at the stations supplied with photographic self-recording instruments. As, however, the results furnished from the latter are not so trustworthy as those obtained by eye-observations of instruments properly exposed, it is contemplated to have the instruments read hourly for at least one year, as soon as the required sum of money is placed at the disposal of the Observatory. Some progress has been made in the reduction of the old registers.

The most important feature during the year's activity has been the addition of first-class Magnetical Instruments. The large Magnetometer did not arrive till the end of the year, but during the latter half of the year the Magnetic Dip was observed

every fortnight, and it is hoped that this part of the activity of the Observatory may be extended during the coming year.

Some time was also spent in gaining experience in photography, and a photographic eyepiece has been ordered for the large Refractor, with which it is intended to photograph Sunspots and other phenomena.

A Rain-band Spectroscope was also added to the instrumental outfit during the autumn, as well as Browning's Solar Eyepiece.

The Earl of Crawford's Observatory, Dun Echt.

The greater number of the observations made at this Observatory during the past year, refer to comets.

Comet *Wells* was observed for place on ten nights, while its spectrum was examined on several occasions, and measured on five nights. This is the first comet which showed, besides the usual hydrocarbon bands, also the sodium lines. The presence of the latter in the spectrum was first noticed on May 27, but the real nature of the line was only recognised on the following night, when it was already much brighter, and found to coincide exactly with the sodium line of a spirit-lamp. Several attempts were made to find the comet at and after perihelion passage, but in vain.

The comet which seems only to have been seen during the total eclipse of the Sun on May 16, was also searched for in the twilight, but without success.

Also the attempts to find the Great Comet, notice of which had been telegraphed by M. Cruls, failed, and but for the telegram obligingly sent by Mr. A. A. Common it is not improbable that it might have escaped notice on Monday, September 18, although, with attention drawn to it, it was easily seen in spite of its nearness to the Sun. The spectroscopic observations secured on that day deserve mentioning. They prove also in this comet the presence of great quantities of sodium vapour, and, what is more important, they leave little or no doubt that also vast masses of iron vapour existed on that day in the comet, and moreover they furnish a splendid proof of Doppler's theory by the observed displacement of all the sodium and iron lines towards red. The unfavourable state of the weather permitted only on two other occasions measurements of the spectrum of this most interesting comet. The details of the spectroscopic observations were published in *Copernicus*.

Of Comet *Barnard*, 1882, only two places were secured.

The eclipse of the Sun on May 16 was observed both with 15·06-inch Grubb Refractor and with the 6-inch Simms Refractor.

With the 15·06-inch Refractor also a fairly satisfactory observation of the Transit of *Venus* was made.

Dr. Copeland having been appointed chief of the Government

Transit of *Venus* Expedition to Jamaica, the instruments and houses lent by Lord Crawford for the expedition were put into good order during the summer, and other necessary preparations made. Dr. Copeland, having started from Dun Echt on October 7, and obtained good observations of the Transit of *Venus* at Jamaica, is expected to return in a few months.

During the year twenty-three Circulars—Nos. 45 to 67—all printed at the Observatory, were distributed. With the exception of No. 53 they all relate to comets. Besides observations they contain fifteen sets of elements and about the same number of ephemerides. Nearly all the telegraphic informations, received and sent, were transmitted by the "Science Observer Code," which answers its purpose admirably. In spite of the inevitable mutilations of some of the words, every message could be perfectly deciphered.

The reductions of the observations are in a forward state.

Considerable progress has been made in the printing of observations connected with the Transit of *Venus* in 1874.

The arrangements respecting the time-gun, time and meteorological observations remain as before.

Mr. Edward Crossley's Observatory, Bermerside, Halifax.

There has been no change in the observational work of this Observatory since the last report. The measurement of double stars and the phenomena of *Jupiter's* satellites have received the largest share of attention. The weather of 1882 was exceptionally bad here, and the observations were much interrupted.

Mr. Huggins' Observatory, Upper Tulse Hill.

The following is a summary of the work of this Observatory during the past year:—

(*a*) On March 7 a photograph of the spectrum of the great nebula in *Orion* was obtained. The spectrum extends from a little below F to beyond M in the ultra-violet. The photographic plate shows a spectrum of bright lines, and also a narrower continuous spectrum probably due to stellar light. The bright stars forming the trapezium in the fish's mouth of the nebula were kept close to the side of the slit, so that the light from the adjacent brightest part of the nebula might pass to the plate. Outside this narrow continuous spectrum a very faint continuous spectrum is suspected. The photograph shows faintly but satisfactorily the four bright lines discovered in the nebula by Mr. Huggins in 1864, and beyond these known lines, in the ultra-violet a new line of great relative strength which has a wave-

length of about 3730. This line appears to correspond to ζ of the typical spectrum of the white stars obtained by Mr. Huggins.* Very faint lines are suspected in the spectrum between Hγ and λ 3730, and also, possibly, beyond λ 3730.

(*b*) On the evening of May 31, a photograph of the spectrum of Comet I. (Wells) was obtained, a comparison spectrum of *a Ursæ Majoris* being taken on the same plate.

The photograph shows a strong continuous spectrum extending from about F to a little beyond H. For the first time since spectrum analysis has been applied to the light of comets, the visible spectrum of this comet consisted principally of bright lines including those of sodium, the usual carbon bands being excessively faint. So also the photographic spectrum differs from that which Mr. Huggins obtained of the bright comet of 1881. The cyanogen group in the ultra-violet, and other lines probably due to carbon, are not to be seen in the photograph, but five brighter spaces between F and H probably indicate groups of bright lines. The positions of the brightest parts of these groups are—

λ 4764
4634
4507
4412
4253

(*c*) From the end of May till September 28 a series of photographs of the Sun was taken under conditions which it was expected would enable the corona to be obtained upon the plates. The slit photographs taken in Egypt on May 17 had shown that the corona light is very strong from about G to H. It appeared probable to Mr. Huggins that by cutting down the Sun's light to this part of the spectrum, and by the use of photography which is very sensitive to minute differences of illumination, those parts of the atmospheric glare which have the corona behind, might be sensibly stronger in the photographs than the parts of the atmospheric light where no coronal light is present.

The photographs were taken with a reflecting telescope by Short, $3\frac{1}{2}$ feet focal length, arranged as a Newtonian, the aperture being reduced to 3 inches. The light was restricted to the small range of refrangibility of from about G to H, by means of screens of coloured glass, and also by a cell containing a strong solution of potassic permanganate. These screens were placed immediately in front of the sensitive surface. The gelatine plates were backed with asphaltum dissolved in benzole. Very different exposures were given. In about twenty plates an appearance peculiarly coronal is seen about the Sun. This does not consist merely of increased photographic action about the sun, but shows distinct forms which were found to accord well with those

* "Photographic Spectra of Stars," *Phil. Trans.* 1880, part ii. p. 669.

in the plates taken in Egypt. In the longer exposed plates the outer corona with its rays of varying length and peculiar rifts is seen; in the plates with a shorter exposure the inner corona, which is more nearly uniform in height, may be seen under suitable illumination. The average heights of the outer and inner coronæ agree closely with the coronæ as seen on the plates taken in Egypt.

On account of the great importance of these results, Mr. Huggins was desirous of having his own opinion confirmed as to the reality of the coronal forms on his plates. Professor Stokes and Captain Abney kindly examined them with much care, and have permitted him to say that in their opinion the corona has really been photographed without an eclipse.

The great Equatorial (belonging to the Royal Society) has been dismounted for improvements since June. It has, therefore, been impossible to continue photographic work on the spectra of the stars and nebulæ; and for the same reason no observations of the great comet of last autumn could be made.

The Earl of Rosse's Observatory, Birr Castle.

The year 1882 was more unfavourable than usual for astronomical work, observations having been made on forty nights only during the ten months in which the assistant was at his post. On 321 nights clouds were recorded at 9 p.m., and 335 nights were classed as more or less cloudy. Rain also is recorded to have fallen on 221 "days." The months of April and May, however, during which Dr. Boeddicker was absent in Germany would, if included, have somewhat increased the proportion of observing nights.

Three sketches of the planet *Mars* and six of *Jupiter* were made during the year with the 3-foot Reflector; also thirty-four sets for nebulæ were made with the 6-foot Reflector.

Some sketches of Comets *b* and *c*, 1881, and of the planet *Jupiter* in the season 1880–1, were published in the course of the year by the Royal Dublin Society; and a series of eighteen sketches of the planet *Mars* when last in opposition are in course of publication by that Society.

A series of sketches of the planet *Jupiter*, made during the season 1881–2, is in our portfolio.

Some lunar-heat determinations, made at intervals by Dr. Boeddicker are in process of reduction, and will probably be employed to confirm, or modify, as the case may be, the extinction and lunar-phase curves, as given by Dr. Copeland.

The Transit of *Venus* of December 6 was seen occasionally with the 3-foot between clouds, the enlarged image being projected upon a screen, but the Sun was invisible at the times of the contacts.

The meteorological observations have been made without interruption the same as last year.

A new polishing machine for 3-foot specula was constructed during the year. It is very similar in general mechanical arrangement to that sent out with the great Melbourne Reflector.* It has, however, been fitted for giving, in addition to the circular and straight strokes hitherto commonly employed, other motions with different relative times of rotation of the two excentrics as in Lassell's last machine.† The machine at its first trial, when the relative velocities of the excentrics were as 104 to 155 and their respective throws $\frac{1}{4}$ and $\frac{1}{3}$ the diameter of the speculum, gave a very good result, and it is hoped that subsequent experiences may be equally satisfactory.

Though it forms no part of the Observatory work, it may be mentioned that Dr. Boeddicker has during the year devoted a considerable amount of time to a discussion of the numerous papers which have from time to time appeared on the influence of magnetism upon the rates of chronometers. It is hoped that the paper, which is being published by the Royal Dublin Society, may be useful to succeeding workers on the subject.

Mr. Wilson's Observatory, Streete, Rathowen.

During the past year the mounting of the silver-on-glass Reflector of 2 ft. aperture by Grubb has been finished in the new Observatory. Observations have been made of the satellites of *Uranus* and *Saturn* and Comet *Wells*. The Transit of *Venus* was well observed in a cloudless sky. Six minutes after first contact the planet could be seen projected against corona, and surrounded by a ring of light. Internal contact $1^h\ 52^m\ 14^s$ S.M.T. No black drop. A series of observations in the infra-red end of the spectrum of different parts of the Sun's surface have been undertaken, and it is hoped that some of the results will be laid before the Society during the year.

* *Phil. Trans.* vol. clix.
† *Ibid.* vol. clxv.

Notes on some Points connected with the Progress of Astronomy during the past Year.

Discovery of Minor Planets, 1882.

The following eleven minor planets were discovered in the year 1882:—

No.	Name of Planet.	Date of Discovery. 1882.	Discoverer.	Place of Discovery.
(221)		January 18	J. Palisa	Vienna
(222)		February 9	,,	,,
(223)		March 9	,,	,,
(224)		March 30	,,	,,
(225)		April 19	,,	,,
(226)		July 19	,,	,,
(227)	Philosophia	August 12	Paul Henry	Paris
(228)		August 19	J. Palisa	Vienna
(229)		August 22	,,	,,
(230)	Athamantis	September 3	De Ball	Bothkamp
(231)		September 10	J. Palisa	Vienna

The Supplement of the *Berliner Jahrbuch* still retains its distinctive character as the almost sole authority for the calculated ephemerides of the minor planets. In the Supplement recently received may be found daily ephemerides for the year 1883, for 43 members of the group, near the times of opposition, the places being given for midnight, Berlin time. There are also 20-day ephemerides giving less approximate places for noon for 112 planets throughout the year. The minor planets which appear to approach nearest the Earth in 1883 are *Isis*, *Phocea*, *Clio*, *Flora*, *Virginia*, *Polyhymnia*, *Fortuna*, *Metis*, and *Juno*, the least distances ranging between 0·895 for *Isis* and 1·180 for *Juno*, the radius of the Earth's orbit being unity.

E. D.

The Comets of 1882.

The number of comets that have actually been seen for the first time during the year is perhaps five, but of these only three have been continuously observed. The remaining two objects of a cometary character that have been reported, though interest-

ing of themselves, are, from various causes, not likely to find a permanent place in our catalogues. Each of these objects will be referred to in chronological order.

At the commencement of the year Comet VIII. 1881 (Swift) was the only comet visible, and observations were procured till the middle of January. As this comet was mentioned in the last Annual Report, no further notice of it is necessary here.

On March 17 a comet was discovered at Albany, U.S., by Mr. C. S. Wells, which was destined to attract considerable attention. At the time of its discovery it was small, bright, with distinct nucleus, and narrow tail. On March 19, from which date observations became frequent and continuous, Prof. Lewis Boss described the object as a great comet in miniature. The breadth of the head was about 30″, the length of the tail 6′ or 8′, and the nucleus shone with the light of a star of the eighth magnitude. An increase in brilliancy was steadily maintained, and early in May the comet was visible to the naked eye. Astronomers had been prepared for this increase of brilliancy, as well as for the subsequent display, by the determination of the orbit, which had been effected by several computers. Dr. Kreutz, from his first elements, predicted a theoretical brilliancy at the time of perihelion passage of nearly 6,000 times the brightness of the comet on March 20; and though subsequent discussion of the elements from improved data modified and somewhat diminished this value, no doubt remained of the interesting character of the orbit and the brilliant spectacle the comet was to present. The small altitude of the comet after sunset, and the bright background of the sky on which it was projected, interfered in some measure with its appearance, but the theoretical brilliancy was sufficiently great to warrant the conjecture that the comet would be visible in daylight. This actually proved to be the case. The comet was seen close to the Sun at many observatories. Possibly the smallest telescope with which it was so seen was the 6 ft. Refractor at Athens, where, on June 10, Dr. Schmidt saw the comet, 2°·8 distant from the Sun's limb. After perihelion passage, in July, the comet was seen, but with greatly diminished splendour, and observations were discontinued in August.

Many sets of elements have appeared; the most trustworthy orbit, though not definitive, is by M. Stefan Wolyncewicz. The perihelion distance is there given as 0·060768 that of the Earth's distance. Notwithstanding this close approach to the Sun, there is no difficulty in reconciling the observations previous to perihelion passage with those made subsequently, a point of some interest in connection with another comet discovered this year. When the observations made at the anomalies $-160°$ and $+152°$ are represented, a very satisfactory agreement is found to exist at intermediate points on the curve.

If the appearance of the comet owing to its unfavourable situation was disappointing, there are not wanting rigorous

observations to show that its brilliancy was even greater than might have been anticipated from the law of reflected light. Dr. Müller, of Potsdam, observing with a Zöllner Photometer, has determined that the light of the comet increased very rapidly, and that on June 6, when last seen, it possessed nearly forty times the brilliancy assigned by theory. Unfortunately, the small altitude of the comet necessitated the employment of a very serious correction, depending upon the extinction of light in the Earth's atmosphere. Dr. Müller has not given the data from which this correction has been taken, though, as he states that he has been engaged some years in investigating its amount, it is to be hoped that this doubtful element has been satisfactorily eliminated, and that Dr. Müller's interesting result will be entitled to implicit reliance.

The spectrum of this comet has increased the interest which its brilliancy awakened. Ever since 1864, when the spectrum of a comet was first observed by Donati, great uniformity has pervaded the spectra examined. All have shown the characteristic bands of hydrocarbon, but in this case, as soon as the comet had attained sufficient brilliancy for its spectrum to be observed, a marked deviation from the ordinary type was apparent; and inasmuch as the comet would approach very near the Sun, it was anticipated that some unexpected phenomena would be manifested. On April 7 the spectrum of the nucleus was seen to be continuous, though feeble and narrow, in which three ill-defined brighter points, corresponding approximately to the carbon bands, were just perceptible. By the 21st the difference between this spectrum and the ordinary type was so strongly marked, that the cometary nature of the object would hardly have been recognised. At the end of May the bright sodium line in the nucleus and neighbouring regions was detected at Dunecht. In the early part of June, when the comet attained its greatest brilliancy, this line under adequate dispersion was seen to be double, and the behaviour of the more refrangible line indicated to Prof. Vogel that the density of the incandescent gas was very great. A want of exact coincidence between the bright sodium lines and the Fraunhofer lines was noticeable on June 6, when the comet had a motion in the line of sight of 3·7 miles per second. The more refrangible portion of the spectrum was photographed by Dr. Huggins after an exposure of the plate for seventy-five minutes, and showed that the essential difference observed in the visible spectrum was maintained at the more refrangible end. On the plate was seen a strong continuous spectrum extending from F to a little beyond H, without any Fraunhofer lines, from which Dr. Huggins concludes that the part of the comet's original light which gives a continuous spectrum, is much stronger relative to the reflected solar light than was the case with the comet last year. The groups in the ultra-violet, presumably due to cyanogen, were not present. In the continuous spectrum five places of greater

brightness were evident, possibly owing to the sodium detected in the visible spectrum.

On May 17, during the total eclipse of the Sun at Sohag, a comet was seen and photographed on the plates prepared to receive the picture of the corona. The comet was distant from the Sun about a solar diameter, and had a tail of half a degree in length. It was never seen again. This observation, possibly unique, recalls, however, the obscure but interesting account of the comet of 418, quoted by Pingré in his *Cométographie.*

On Sept. 13, Mr. Barnard, of Nashville, Tennessee, discovered a faint telescopic comet. Never attaining any great brilliancy, and moving rapidly southwards, it failed to attract much interest. It remained in view of northern Observatories some weeks, passed through its perihelion on Nov. 12, and has been observed since at the Cape of Good Hope, so that ample materials exist for the determination of the orbit, which is probably parabolic.

The Great Comet.—Information of the discovery of this comet first reached Europe on Sept. 12, by a telegram from M. Cruls, of Rio Janeiro; but in the southern hemisphere the comet had been seen as early as the 3rd, and observations had been made by Mr. Tebbutt and Mr. Finlay on the 8th. The announcement of the appearance of another comet, visible to the naked eye, the fourth which had been seen in twelve months, was however of inferior interest to the intelligence of the independent discovery of the same comet by Mr. Common, who, following a plan of observation which he had for some time pursued, detected it near the Sun's limb on the morning of Sept. 17. Mr. Common's observation showed that the comet was approaching the Sun at the time, but owing to clouds the object appears to have been lost sight of a little after noon. The interesting phenomenon therefore of the approach of the comet to the Sun's limb, and the actual transit over the Sun's disk, was missed; but more favourable weather at the Cape of Good Hope permitted Mr. Finlay and Dr. Elkin to make this unique observation. The comet was traced right up to the limb of the Sun, where it disappeared as suddenly and as effectually as the occultation of a star by the Moon. The distance of the comet from the Earth was [9·99191], the radius vector of the Sun [0·00192], so that it passed between us and the Sun, but the observers did not know at the time whether the comet was transiting the Sun or whether it was occulted by it, so completely had every trace of the nucleus, which was 5″ in diameter, vanished. Similar observations to those recorded by Pastorff and Stark, and which have been thought to refer to the transit of comets over the Sun, would seem therefore to need a different explanation.

The elements of the orbit when they appeared disclosed an unexpected feature—namely, their close agreement with those of the comets of 1843 and 1880, a coincidence that has given rise to various hypotheses, specious and startling. The identity of

the comet of 1843 with that of 1880 had been rather reluctantly admitted, since the classical investigation of Hubbard had shown that the earlier comet was moving in an orbit of 533 years, and it had been first necessary to prove that the observations of 1843 could be represented by an orbit of about 37 years. This attempt was only partially successful. If a period of 37 years is to be substituted for that which is rigorously deduced from the observations, it necessitates an increment of −·000498484 to the excentricity, and corresponding corrections to the other elements. Since Prof. Hubbard has calculated the effect on the elements of an arbitrary change in the excentricity, these corrections can be immediately introduced. This alteration in Hubbard's elements has been effected by Prof. Weiss, who has shown that when the observations are compared with the theoretical places derived from the new elements, the probable error of a single observation is increased from 8″·4, the value found by Hubbard, to 39″·4. If fresh elements be sought, which is desirable, since the coefficients of the variations of the elements are only applicable so long as the functions can be considered linear, the residual errors, though considerably reduced, remain conspicuously greater than those found by Hubbard, as shown in the table below.

Date. 1843.	Independent Orbit.		Deduced Orbit.		Hubbard's Orbit.	
	Δα	Δδ	Δα	Δδ	Δα	Δδ
	″	″	″	″	″	′
Mar. 5	+ 7·0	+18·4	−117·9	+73·2	+25·7	+12·9
25	+19·4	−48·6	+ 39·5	−12·9	+ 4·6	+ 5·5
Apr. 19	−14·5	+35·1	− 54·3	+61·1	− 8·7	+ 9·3

This want of agreement was, however, explained away by supposing that the centre of gravity did not correspond with the centre of condensation, and that an argument drawn from the comparative smallness of the residuals was not final.

There was but little difficulty in representing the observations of the 1880 comet by an ellipse of 37 years' period, but in this Dr. Meyer, of Geneva, was greatly assisted by the small length of the comet's heliocentric path—viz. three degrees. He has decided that the observations can only be satisfied with an ellipse whose period lies between the limits 31·5 and 47·7 years, but this conclusion is arrived at simply by considering the effects of the variation of the excentricity on the other elements. No attempt has been made to represent the observations by an ellipse of 533 years, the other elements of the orbit being independently derived, though the necessity of so doing was proved by Prof. Weiss in the previous case.

But after it had been decided to accept the period given by the supposition of the identity of the two bodies, rather than that derived from the discussion of the 1843 observations, which were scattered over an arc of only eight degrees of true anomaly, it was inconvenient and perplexing to find another magnificent

comet moving in the same track, after an interval of only $2\frac{1}{2}$ years. To account for this phenomenon, a theory, to which the name of Prof. Klinkerfues is particularly attached, was resuscitated and obtained some favour. This astronomer had supposed that the comets of 1880, 1843, 1668, and B.C. 371 were each apparitions of the same object, whose orbit was being gradually curtailed by successive passages through the "resisting medium." It was contended that if one-thirteen hundredth part of its initial velocity was destroyed by the resistance of the solar vapour, the contraction of the orbit would be such as to approximately coincide with the appearances observed, and that the next return might be anticipated in 1897. A reappearance in 1882 was of course premature, and necessitated a still further reduction of the axis major, yet as there was some difficulty in reconciling the observations made before perihelion with those made immediately after, and as this difficulty could be easily removed or explained by supposing some resistance to have been offered to the comet when in the neighbourhood of the Sun, this hypothesis did obtain for a time some sanction. Continued observations have, however, to some extent removed this apparent disagreement between the observations made on the two arcs of the ellipse, and have conclusively proved that no very short period will satisfy the observations. On the other hand, no parabola nor very extended ellipse will represent the observed path. Definitive elements are not yet known; but the best orbits yet published give such periods as 794, 843, or $652\frac{1}{2}$ years, indicating axes major not greatly different from that found by Hubbard.

An alternative theory which was suggested in 1880 obtains now a more general support—namely, that the three comets have had in the past a common origin, but by a process of gradual disintegration, the original mass has detached fragments which, pursuing slightly different paths, arrive at their perihelia at irregular intervals. The bifurcated orbit of the dichotomised comet of Biela furnishes an example of the diverging paths, along which portions of the same comet may move, becoming gradually separated in space.

The gradual dissolution of the comet itself, suggested by the latter theory, receives some support from the behaviour of the comet while under observation. Not only has the inconstant form of the nucleus been so pronounced as to introduce additional difficulties in the determination of the orbit, but Dr. Schmidt has observed (Oct. 9) a nebulous object in the neighbourhood of the comet, which there is some reason to believe is a detached fragment of it. This nebulous body was seen only on three consecutive mornings at a very low altitude, and with condensations so ill defined that the observations were only approximate. The consequent determination of the orbit is therefore very insecure. The elements, however, that have been derived do show some similarity, particularly in the small perihelion distance, with those of the great comet, and suggest

strongly the idea of a past intimate connection. But the final settlement of the entire question must await the complete discussion of the observations now in progress.

The appearance of the comet, the structure of the tail, the formation of the head, &c., have been graphically described by many observers in current scientific periodicals of easy access; and photographs taken at the Cape and elsewhere have preserved the general features. The spectrum has been the subject of special study, and has indicated some fresh facts of interest. It is curious to notice, that while the spectrum of comet *Wells* was continuously observed as the comet approached the Sun, and illustrated the effects of great and increasing excitement, the spectrum of this comet could only be observed as it receded from perihelion, and consequently the phenomena that were observed in the preceding case might be expected to exhibit themselves here in a reversed order. This, to a great extent, actually occurred. When the spectrum was first seen on Sept. 18, the sodium lines were at once seen distinctly double, both in the nucleus and parts adjacent, while a number of other bright lines coinciding with the more prominent iron lines were visible. Of the ordinary banded spectrum there was no trace. On Sept. 29 the iron lines had quite disappeared, the D lines were not separable, and indications of the ordinary comet spectra were apparent, while at the end of October, when the comet had reached the Earth's distance from the Sun, all trace of the sodium lines had vanished, and the three bands of hydrocarbon were distinctly present. It has been suggested by Dr. Hasselberg and others that the entire explanation of the phenomena witnessed cannot be found in the simple increase or diminution of temperature, depending on the distance of the comet from the Sun. For though an increase of temperature might account for the appearance of metallic lines, it does not satisfactorily explain the simultaneous disappearance of the characteristic carbon bands. The entire solution, it is submitted, is to be found by supposing that the cometary light is to some extent due to electric discharges, a supposition the more tenable, since laboratory experiments conducted on hydrocarbons and sodium vapour, have shown how preferential is the electric discharge when both these vapours are present.

W. E. P.

The Comet of 1812.

For this comet Encke had computed an orbit of about 70 years period, and consequently the return of the comet might have been expected very shortly. It was therefore desirable, as the time approached, to have a more rigorous investigation, in order to predict the date of its return within narrower limits, and supply the means for a systematic search for its discovery.

This task MM. Schulhof and Bossert have undertaken, and carried to a successful issue, with a care and elaboration that astronomers will appreciate. The observations have been re-reduced in order to introduce the best places of stars of comparison, and correct values of astronomical constants. In those series of observations in which systematic errors were suspected, special precautions have been taken to eliminate their effects from the final result. The solution of the equations of condition has been so effected that each of the derived corrections to the elements is accompanied with a term depending upon the correction to the excentricity. If this correction be made =0 the most probable period is 73·18 years, but as the excentricity correction may vary between the limits ±0·0018 the uncertainty in the period unfortunately amounts to 4·5 years. According to three possible combinations in which the observations may be grouped, the authors derive periods of 73·23, 73·19, and 75·01 years, and the conclusion is that the period is probably longer than 73·18 years. The effect of perturbation of the four superior planets has been calculated up to May, 1884. The return of the comet is thereby accelerated 445 days, and MM. Schulhof and Bossert have fixed Sept. 3, 1884 for the date of the next perihelion passage. As in 1812 the date of the perihelion was Sept. 15, the path in the heavens would nearly coincide with that of 1812, and the chances of its detection would be correspondingly great. If, however, the nearest approach to the Sun occurs between March and July, the chances of reobservation are slender.

Prof. Kirkwood had called attention to the possible intimate connection between this comet and that of De Vico of long period, since, with the exception of the longitude of the ascending node, there was a general similarity in the elements of the two orbits. This suggestion is favourably received, and it is further pointed out that each comet approaches closely to the orbit of *Venus* at about the same true anomaly.

Comet 1812.	True anomaly 341°·2.	Distance from *Venus*' orbit	0·076.
,, 1846 IV.	,, 347·1.	,, ,,	0·049.

Most extensive ephemerides are furnished by combining the values of true anomaly with different values of the solar coordinates, and which, while they point out the more likely positions in which the comet may be sought, decide at once whether any comet accidentally discovered is that whose return is expected. This latter portion of the work had been to some extent anticipated by Dr. Winnecke, who published, in 1877, a system of sweeping ephemerides, based, however, upon the less rigorously deduced elements of Encke.

W. E. P.

The Transit of Venus, 1882.

Three different methods have been applied to obtain a determination of the Sun's distance from observations of the transit of *Venus* in 1882, December 6.

The British have relied chiefly on the method of contacts; the Americans chiefly on the photographic method; the Germans on direct Heliometer measures; whilst the French have combined the method of contacts with some attempts at photography. Two Belgian expeditions have been sent out, one under M. Houzeau for Texas, the other under M. Niesten for Chili, furnished with heliometers of a novel construction devised by M. Houzeau; but no information of the success of these expeditions has hitherto reached us.

It would appear that sufficient observations have been obtained to give each method a fair trial.

The British arrangements were rendered more complete than would otherwise have been the case from the existence of Observatories at the Cape of Good Hope, Mauritius, Sydney, Adelaide, and Melbourne, in the south; and the assistance rendered by the Canadian Government in the north.

The readiness and liberality shown by the Governments of the different Colonies to assist the work have rendered the operations much more complete than could otherwise have been the case. The devotion of funds to such an object is a proof of the intellectual, as well as of the material, prosperity of our Colonies and of their kindly feelings towards the old country.

The following is a list of the stations occupied by the British, with the names of observers.

Retarded Ingress and Accelerated Egress.

The following three stations were occupied by observers from England, and the contacts were observed both at Ingress and Egress at all three stations:—

Stations.	Observers.
Bermuda	Mr. J. I. Plummer, of Orwell Park Observatory. Ipswich; Lieut. Neate, R.N.
Jamaica	Dr. Copeland, of Dun Echt Observatory, Aberdeen; Capt. Mackinlay, R.A., and Dr. Pearson, of Emanuel College, Cambridge. Mr. Hall not yet reported.
Barbadoes	Mr. Talmage, of Leyton Observatory, Essex, and Lieut. Thomson, R.A.

The following stations were equipped by the Canadian Govern-

ment. The instruments used were from four to six inches aperture :—

Stations.	Observers.
Winnipeg	Prof. McLeod. 2 contacts observed.
Woodstock	Prof. Wolveston.
Toronto	Mr. Carpmael, Superintendent.
Kingston	Prof. Williamson. 3 contacts observed.
Whitby...	Prof. Hare.
Cobourg	Prof. Bain. 1 contact observed.
Belleville	Mr. Shearman.
Ottawa	T. L. Blake, Esq., Dominion Land Surveyor. 4 contacts observed.
Montreal	Prof. Johnson.
Quebec	Dominion Observatory, Lieut. Gordon, R.N.
Halifax	Mr. A. Allison.
Fredericton	Prof. Bryden Jack.

The observers were all trained by Lieutenant Gordon, who visited Oxford for the purpose of making himself acquainted with the kind of contact to which attention was chiefly directed. The instruments were all good 4- and 6-inch telescopes, and powers of from 120 to 150 were used. Time-signals were interchanged between all the stations and the observatories of Toronto and Quebec. Although the observations have been unfortunately lost at many of the stations, those secured will be of the greatest value.

Some few observations have been obtained in the British Isles, and at Rome, Munich, and Lisbon; but the weather was generally unfavourable throughout Europe.

Accelerated Ingress.

Stations.	Observers.
The Cape Observatory .	Mr. Gill, H.M. Astronomer, and Staff.
Aberdeen Road ...	Mr. Finlay, B.A., First Assistant of the Cape Observatory; Mr. Pett, Third Assistant.
Montagu Road ...	Mr. Marth, F.R.A.S., and Mr. C. M. Stevens.
Natal	Mr. Neison, F.R.A.S.
Madagascar	Rev. S. J. Perry, Rev. W. Sidgreaves, Comm. Aldrich, H.M.S. "Fawn," Mr. Carlisle.

Three contacts were observed at this station.

Stations.	Observers.
Mauritius	Mr. Meldrum (contacts at Ingress well observed).

Retarded Egress.

The details have not yet been received from the different stations, but in New Zealand the observers—Col. Tupman, R.M.A., and Lieut. Coke, R.N.—have successfully observed the contacts, as well as several Colonial observers, provided with adequate instrumental means.

Melbourne.—Mr. Ellery and staff have been successful in observing the contacts and in securing some photographs.

Adelaide.—Mr. Todd reports that he has obtained an exceedingly good internal contact from a station at some little distance from Adelaide.

Brisbane.—Observations near this station were prevented by clouds. The loss of these observations is greatly to be regretted, as there were three observers at the station: Capt. Morris, R.E., Lieut. Darwin, R.E., and Mr. Peek, who had provided himself with an equipment and joined this party at his own expense.

Sydney.—Mr. Russell and his staff had made elaborate arrangements for observing the transit, but clouds prevented anything being done at these stations.

Capt. Wharton, of H.M.S. "Sylvia," has observed near Sandy Point, Straits of Magellan, both the Ingress and Egress. These observations afford a fair difference of duration as compared with the northern observations, and will be valuable as a check upon the Ingress and Egress observations, because but little affected by error in the adopted value of the parallax.

The method of contact, like every other method, has its difficulties; but these appear to be dependent solely on the possibility of three kinds of contact being mistaken for each other. There is an appearance of light breaking through at the point of contact when the atmosphere of the planet *Venus*, or the penumbra, first comes upon the Sun's disk. This is sometimes called geometrical contact, or "first appearance of light," and in case of broken weather or clouds there would be great danger of the observer taking this for the "contact" as defined by the last appearance of any well-marked and persistent disturbance of the illumination of the Sun's limb near the point of contact, or the first appearance of direct sunlight. There is also seen after this "contact," in cases where the sky is exceedingly clear and the attention of the observer is *directed* to the point, some slight flickering, shadowy disturbance which gradually fades away, but is of so faint and undistinguishable a character that it could never by any observer be mistaken for the "contact" phase; but, although this is the case, unless care be taken in describing the phenomena seen, persons who have never themselves seen a transit of *Venus* might well be mistaken as to the observer's meaning, and might possibly be inclined to consider such observations as referring to the "contacts." These possible kinds of contact are, however, so widely separated

that no real difficulty should be encountered in referring the observation to the proper phase.

The American expedition to the Cape has been completely successful in securing the required observations; and it is understood that the expedition to Tasmania has also been successful. The weather generally in the northern States of America appears to have been of a broken character: but sufficient photographs have been obtained to afford a fair trial of the photographic method.

The following are the French stations:—

Mission de Port-au-Prince.

MM. D'Abbadie, Membre de l'Institut;
Chapuis, Lieutenant de vaisseau;
Callandreau, Aide-astronome à l'Observatoire de Paris.

Mission du Mexique.

MM. Bouquet de la Grye, Ingénieur hydrographe de la Marine;
Héraud, Ingénieur hydrographe de la Marine;
Arago, Lieutenant de vaisseau.

Mission de la Martinique.

MM. Tisserand, Membre de l'Institut;
Bigourdon, Aide-astronome à l'Observatoire de Paris;
Puiseux, ,, ,, ,,

Mission de la Floride.

MM. le Colonel Perrier, Membre de l'Institut;
le Commandant Bassot;
le Capitaine Defforges;
Tourenne, Photographe.

Mission de Santa-Cruz.

MM. Fleuriais, Capitaine de frégate;
Le Pord, Lieutenant de vaisseau;
De Royer de Saint-Julien, Lieutenant de vaisseau;
Lebrun, Naturaliste.

Mission du Chili.

MM. de Bernardières, Lieutenant de vaisseau;
Barnaud, Lieutenant de vaisseau;
Favreau, Enseigne de vaisseau.

Mission du Chubut.

MM. Hatt, Ingénieur hydrographe de la Marine;
Mion, Sous-ingénieur hydrographe de la Marine;
Leygue, Lieutenant de vaisseau.

Mission du Rio-Negro.

MM. Perrotin, Directeur de l'Observatoire de Nice;
Delacroix, Lieutenant de vaisseau;
Tessier, „ „
Guénaire, Photographe.

The German expeditions have all been placed on the American continent. They have all been partially successful in observing the contacts; but sufficient heliometer measures have, it is understood, been obtained to give this method also a fair trial.

The longitude determinations made in connection with the Transit of *Venus*, 1882, will, of course, have a value quite independent of the use made of them in the reduction of the observations of the transit. The principal determinations are—the connection of the New Zealand and Australian stations *inter se*, and through Port Darwin, Singapore, and Madras with Greenwich; the connection of Madagascar through the Cape Observatory with Greenwich; the connection of the South African stations with the Cape Observatory; and the connection of Bermuda through New York with Greenwich. The telegraph lines have in all cases been placed at the disposal of the observers for carrying out the work. The thanks of astronomers are due to the different governments, companies, managers, and telegraphists for the assistance afforded.

In all cases where the position of *Venus* has to be referred by measures to the Sun's centre there are of course difficulties presented, when working to the small quantities with which we are now concerned in these inquiries, by the necessity for refraction corrections and possible systematic errors of scale value under the circumstances of observation and by unequal contraction or distortion of photographic films, and the successful elimination of such errors from the results can hardly be asserted except from the agreement between the measures obtained at different stations.

It will, of course, be some time before the different results can be laid before us; but their publication will be received with the greatest interest. Our successors can hardly charge us, at least, with having made no serious effort to utilise the opportunity presented to us by the occurrence in our day of a transit of *Venus*.

E. J. S.

M. Gogou on a Lunar Inequality of Long Period due to the Action of Mars.

In Vol. xxxviii. of the *Monthly Notices*, Mr. Neison announced the existence of an inequality of long period in the mean longitude of the Moon due to the action of *Mars*, the coefficient of which amounted to $7''{\cdot}55$, the period being 406 years. In an elaborate paper presented to the Faculty of Sciences of Paris in order to take the degree of Doctor in Mathematical Science, M. Gogou has investigated this inequality anew, taking into account many terms which had been neglected by Mr. Neison. He shows that even in the first approximation it is not sufficient to regard the elements of the Moon's orbit as constant when taking into account the disturbing action of *Mars*, but that it is necessary likewise to consider the modification of this disturbing action produced by variations in the lunar elements due to the perturbing action of the Sun. He also takes into account the inclination of the orbit of *Mars* to the ecliptic.

In this investigation M. Gogou follows the method laid down in Delaunay's Lunar Theory, a method of which he shows a complete mastery. The calculations are necessarily very long, but they appear to have been most carefully made. M. Gogou has had to calculate the quantities ordinarily denoted by $b^i_{\frac{7}{2}}$, $b^i_{\frac{9}{2}}$, $b^i_{\frac{11}{2}}$, and $b^i_{\frac{13}{2}}$, and their differential coefficients for values of the index i extending from 18 to 25.

For such high values of the index, the method of deriving the quantities b^i successively from the first two of them, b^0 and b^1, would have led to most inaccurate results.

The definitive result at which M. Gogou arrives is that the coefficient of the inequality of the Moon's mean longitude now in question only amounts to

$$0''{\cdot}00034,$$

a quantity which is, of course, absolutely insensible.

It is difficult to see how the enormous difference between this result and Mr. Neison's originates.

M. Gogou has shown that it does not arise from the omission of the terms neglected by Mr. Neison. It may be mentioned that Professor Adams has minutely verified several of M. Gogou's values of the quantities b^i, and their differential coefficients.

Oppolzer's "Syzygien-Tafeln."

These tables, which form Publication XVI. of the Astronomische Gesellschaft, are intended to supply a simple and convenient means of finding very approximately the time of

New or Full Moon, particularly in the case of an ecliptic syzygy, and of calculating all the circumstances of an eclipse, without the necessity of having recourse to the Solar and Lunar Tables.

The form of the tables is adapted to the method of calculation employed in Hansen's Theory of Eclipses.

Compendious ecliptical tables intended to answer the same purpose were published by Hansen himself in the *Berichte der Sächsischen Gesellschaft* for 1857, and in the same publication for 1863 he gave the analysis on which the tables were founded. Nearly the same method has been employed in the formation of the present tables, but the approximation is carried further, and the results are given with much greater fulness of detail. The periodic quantities tabulated depend on eight arguments only, but in the formulæ given in the Introduction, the values of many more small terms are added.

Complete formulæ for the calculation of eclipses by means of the tables are given, as well as examples of their application.

In an Appendix, M. Oppolzer compares the circumstances of many of the eclipses recorded in ancient history with the results of his ecliptical tables. One of the tables contains the empirical corrections which he finds it necessary to apply to the arguments at remote epochs, in order to produce a better agreement between the calculated and the observed results.

The Harvard College Observatory Catalogue of Stars for 1875.

This important Catalogue, which is published in vol. xii. of the *Annals*, has lately been carefully discussed in the *Memoirs* of the American Academy, vol. x., by Prof. Rogers, who had made the observations of the stars, superintended their reduction, and determined their proper motions.

The comparison of this Catalogue with others is interesting, inasmuch as the method of observation differed in some respects from that in common use. Spider-lines were replaced by lines on glass, in order to avoid possible errors due to their weight and to the effect of moisture. Stars were then observed between double lines instead of when bisected by single threads, and declinations were determined by transits over oblique lines; the especial advantage of the last method being that the instrument is not touched during the observation.

This Catalogue is constructed from observations extending from April 1871 to May 1872, published in vol. x. of the *Annals*, combined with two series of observations made during the years 1874 and 1875. The observations of 1871 and 1872 depend upon the places of the provisional Catalogue of 539 stars published in the *Vierteljahrsschrift der Astronomischen Gesellschaft*, 1869, which consists of 336 principal stars whose positions were at that time

known within narrow limits, and of 203 secondary stars whose places were known with less precision. The observations of 1874 and 1875 depend upon the Pulkowa Catalogue of Zusatzsterne, published by Professor Struve in 1874. In his discussion of the Catalogue Prof. Rogers shows that the systematic deviation of these Pulkowa observations from the final positions of the several stars given by Auwers in his Fundamental Catalogue (*Publication der Astronomischen Gesellschaft*, xiv.) is quite large, especially in declination. In so far, therefore, as these stars were used in the determination of the instrumental constants for the years 1874 and 1875, there is a departure from the system upon which the 1872 observations are based.

The Primary Catalogue consists of 334 stars, and the Secondary Catalogue of 284 stars, the positions being derived from the mean of the three places for 1871–2, 1874, and 1875. giving to each a weight proportional to the number of observations, and giving one-half weight to the lower culminations, In the Primary Catalogue the annual variations have been computed with Bessel's constants, and include the provisional values of the proper motion given in the *Vierteljahrsschrift der Astronomischen Gesellschaft*, vol. iv.

In the Secondary Catalogue the provisional values of the proper motion given in vol x. of the *Annals* are employed. These values rest upon the assumption that if the positions given by different authorities at various epochs are reduced to a homogeneous system, the systematic error belonging to each authority will not appear in the resulting proper motion.

In his very able memoir on "A Comparison of the Harvard College Observatory Catalogue of Stars for 1875·0 with the Fundamental Systems of Auwers, Safford, Boss, and Newcomb," Professor Rogers remarks that it is obvious that in the reduction of a given series of observations from the system of one fundamental catalogue to that of another system, the most independent method of procedure would be to apply to the given series the systematic corrections derived from comparing the system upon which it is based with that to which it is to be reduced. The fact that the Harvard College Catalogue for 1875 depends upon two systems which differ systematically makes it imperative that the comparison shall be made directly with Auwers. He has accordingly given in his memoir the Catalogues of primary and secondary stars reduced to the fundamental system of Auwers; to which are appended the differences between the Harvard College Catalogue and Auwers, Safford, Boss, and Newcomb, the last three Catalogues being reduced to the system of Auwers.

The result of the comparison is to show that the Harvard College observations are of a very high order of excellence, reflecting great credit upon Professor Rogers, who had made them.

Double Star Observations.

The energy displayed by observers of late years in this interesting branch of astronomy has in no way abated, and some important contributions have recently appeared.

Mr. S. W. Burnham, whose work in this direction is not only so extensive but also of such high excellence, has recently communicated to the Society a valuable series of Double Star Observations, made in 1879 and 1880 with the 18½-in. Refractor of the Dearborn Observatory, Chicago, which will appear in the *Memoirs*.

Since 1875 the Cincinnati Observatory has been steadily devoted to the micrometric measurement of double stars. The first publication issued by Professor Ormond Stone, the Director, contained a catalogue of 50 new double stars discovered at that Observatory, and which has been already noticed by the Council. The following issue was devoted to the publication of the Double Star Observations made by Professor O. M. Mitchel at the old Observatory at Cincinnati, in the years 1846 to 1848. This series is important, as, with the exception of the observations of Dawes and Mädler, very little micrometric work on double stars appears to have been undertaken at any observatory during this period. In 1875 Professor Ormond Stone decided to devote the 11-in. Refractor of the Observatory to observations of double stars between 15° and 35° of South Declination—a region where our knowledge of double stars depended almost entirely upon the observations of Dunlop, Sir John Herschel, Jacob, and Powell, of which a large portion of Sir John Herschel's stars had never been micrometrically measured. The original object of the observations was subsequently modified to the preparation of a general catalogue of known double stars situated between the equator and 30° South Declination.

The observations up to 1880, September 1, contained in Numbers 3 to 6 of the Publications of the Observatory, consist of the following results:—

No. 3.	371	Observations of	166	Double Stars.
4.	930	,,	517	,,
5.	2250	,,	1054	,,
6.	750	,,	455	,,

The above observations are, however, not confined to southern stars, but include several objects which Mr. Burnham had indicated as needing re-observation, besides some other northern stars.

Northern stars have been usually observed once, and southern stars twice, in position-angle and distance.

The work has been steadily pursued by Professor Ormond Stone, and the results cannot fail to be of value.

Mr. Russell, of the Sydney Observatory, has presented to the Society a paper, which will appear in the *Memoirs*, containing a micrometric revision of Sir John Herschel's Southern Double Stars, and which will form an interesting comparison with the Cincinnati Observations.

Professor Schiaparelli has recently published in the *Rendiconti del R. Istituto Lombardo* a valuable series of measurements of 32 known binary stars having rapid orbital motion. These were made with the Merz 8½-in. Refractor of the Brera Observatory at Milan, in the years 1875–1882. The total number of observations is 967, and they have evidently been made with the greatest care, and bear favourable comparison with the best micrometric measurements in existence. The comparison with Dembowski, for example, yields the following result:—

Distance.	Position-angle.	S.—D. Distance.	No. of Stars.
″ ″ 0—1	° −0·55	″ −0·023	16
1—2	−0·44	+0·035	14
2—4	−0·10	+0·052	21
4 and above	−0·04	−0·026	12

Professor Schiaparelli's results will form important data in the discussion of the orbits.

The Leipzig Observatory has only lately published some observations of 162 double stars made with the Equatorial by Dr. R. Engelmann in the years 1864–1867. The details of the observations are given, and the comparison with good observations at the same epoch shows a satisfactory agreement.

In vol. i. of the Publications of the Washburn Observatory, Wisconsin, the Director, Professor Edward S. Holden, has published a list of 60 new double stars discovered mostly by himself in the zone observations at that Observatory, from April 23 to September 30, 1881, and which have been micrometrically measured by Mr. S. W. Burnham. The stars vary in distance from 0″·6 to 7″, and the measurements average about three determinations of position-angle and distance for each star. Following this catalogue is a list of 88 new double stars discovered and micrometrically measured at the Washburn Observatory in the same period by Mr. Burnham; making 148 new double stars discovered at one Observatory in five months. This speaks for itself for the activity and energy of the Director, Professor Holden, and his able assistant, Mr. Burnham. In the same volume is published a series of measures by Mr. Burnham of about 150 double stars selected from his MS. General Catalogue of Double Stars, as specially needing observation. In these observations Professor Holden states that two observers participated, thereby saving much of the time usually

consumed in moving the dome and observing chair, setting the instrument, reading the circles and chronometer, recording the observations, and taking the means of the separate settings. By these means he states that from 25 to 30 stars can be completely observed in one night. The whole of the measurements in the above three lists appear to have been made in the period from April to September, 1881. Professor Holden deserves congratulation for the large amount of work on double stars of an evident high character produced at his Observatory in so short a time.

The Micrometric Measurements of the Harvard College Observatory.

A large quantity of micrometric work having accumulated at the Harvard College Observatory during the period 1866 to 1881, these have been reduced and published in vol. xiii. of the *Annals*. The observations are of a miscellaneous character: 1. A good series of double star measures made with a filar micrometer, mostly under the direction of Professor Winlock. This comprises a list of 172 new double-stars with approximate elements; and micrometric measurements of nearly 350 known double stars.

2. Micrometric, spectroscopic, and general observations of about 280 nebulæ—the positions of several being determined by measurements from known stars.

3. Micrometric observations of the satellites of *Saturn*, *Uranus*, and *Neptune*, made by Professor Winlock in the years 1866–1868. This series does not contain any observation of *Hyperion*, *Mimas*, *Ariel*, or *Umbriel*.

4. A very extensive series of observations of the satellites of *Mars* in 1877 and 1879 made under the direction of Professor Pickering.

In 1877 the measurements were made with a filar micrometer on the 15-in. Equatorial, reducing the light of *Mars* by covering a portion of the field with coloured glass and placing the planet behind its edge. The results for 1877 have been already published in the *Astronomische Nachrichten*. In 1879 a large series of observations of the satellites was obtained, comprising for position-angle, 75 measurements of *Phobos*, and 207 of *Deimos*, and for distance, 53 measurements of *Deimos*—no observation of the distance of *Phobos* being recorded. The observations are very fully discussed, and a good accordance is established between the two series made in 1877 and 1879, though different micrometer screws were used in each year.

5. Observations of asteroids with micrometrical measurements from comparison stars.

6. Observations of comets and comparison stars.

7. Occultation of stars and planets.

Researches on Stellar Parallax.

Professor Asaph Hall has recently published a determination of the parallax of *a Lyræ* from observations made by himself with the 26-inch refractor of the Naval Observatory. The observations were made on seventy-seven nights between May 24, 1880, and July 2, 1881. The method adopted was to observe simply the difference of declination of *a Lyræ* and its companion of the tenth magnitude. In the observations two kinds of illumination of the wires of the filar micrometer were used: A, dark wires with a bright field, and B, bright wires. The resulting values of the parallax for each method are

$$\text{A. } \pi = 0''.1556 \pm 0''.00764$$
$$\text{B. } \pi = 0''.2080 \pm 0''.00827.$$

Taking the mean by weight of these values, the final result gives

$$\pi = 0''.1797 \pm 0''.005612.$$

The time required for light to pass from this star to our Sun is 18·11 Julian years.

Professor Hall has also determined the parallax of 61 *Cygni* from observations on sixty-six nights, from October 24, 1880, to December 7, 1881, dark wires in a bright field being employed, from which the following result is obtained:

$$\pi = 0''.4783 \pm 0''.01381.$$

The time required for light to pass from this star to our Sun is 6·803 Julian years.

Professor Robert S. Ball, the Astronomer Royal for Ireland, in his search for stars with appreciable parallax, selected for observation 6 *Cygni*, a well known double star with large proper motion, the star B of the pair being employed for the investigation. A systematic series of measurements of the distance of a small 10·5 magnitude star was made from October 3, 1880, to December 22, 1881. The measures were made in a dark field with bright wires, and the following determination of the parallax is obtained:

$$\pi = +0''.482 \pm 0''.054.$$

Professor Ball considers this result as merely provisional; but he thinks it can hardly be doubted that a parallax of very considerable amount really exists. He further remarks that it is impossible not to be reminded of 61 *Cygni*, which is in the

same constellation, and the parallax of which is about the same amount. Both doubles are of the same general character, and have each a large proper motion.

Dr. O. Backlund has investigated some observations for determining the parallax of the star *Bradley* 3077, made by M. Wagner with the Transit Instrument of the Pulkowa Observatory. The method adopted was the determination of differences of Right Ascension between it and neighbouring stars. The observations were, however, made under rather unfavourable circumstances for the determination of parallax. The resulting parallax obtained from comparison with one star is

$$\pi = +0''.20 \pm 0''.080,$$

and from comparisons with another star

$$\pi = +0''.21 \pm 0''.078.$$

These values of π agree, within the limits of probable errors, with the value deduced by Gyldén, from observations made with the Equatorial of the Stockholm Observatory.

$$\pi = +0''.28 \pm 0''.045.$$

The Constant of Precession.

For an exact determination of the Constant of Precession two sets of data are required—viz., two well-founded equinoxes and a number of stars observed near both their epochs. It is, of course, also advantageous to have the epochs separated by as long an interval of time as possible. Dr. Dreyer, in his "New Determination of the Constant of Precession" (*Copernicus*, No. 20), has made use of data which are well suited in some respects to give a useful value of the Constant. He has compared the places of about 3300 stars as given in Lalande's *Histoire Céleste* with their places as given by Schjellerup in his great Catalogue of stars situated between $+15°$ and $-15°$ Declination. Besides having such a large number of stars to form the basis of his investigation, Dr. Dreyer points out that the interval of time between the two epochs of observation is also favourable, being 66 years. Lalande's observations of stars near the equator were made during the years 1793–1801, whilst Schjellerup's observations comprise the time from Sept. 1861 to Dec. 1863. The Right Ascensions only were used, as the foundation of these appeared more secure than that of the Declinations.

For the reduction of the observed places to 1800·0 the tables of reduction by the late Von Asten were used, as in Dr. Dreyer's opinion Baily's Catalogue is useless for any purpose requiring

accuracy, and should only be used as a mere index to the stars observed by Lalande. The mean R.A.'s for 1800·0 having been computed, they were brought up to Schjellerup's epoch 1865·0 by using the mean of Baily's precessions, computed from Bessel's Constant, and of Schjellerup's precessions, computed from Struve's Constant. The comparison with Schjellerup's places was then made (all errata that could be discovered having been corrected), and the differences exceeding $0^s{\cdot}7$ examined by comparing all the Catalogues at the author's disposal in order, if possible, to detect proper motion, the correction for which was applied if the quantity appeared at all trustworthy. The mean result has also to be corrected for errors in the equinoxes on which the R.A.'s are founded, and Dr. Dreyer decided to use the corrections given in Newcomb's "Equatorial Fundamental Stars," which would also make his result comparable with the older values of the Constant of Precession when reduced to Newcomb's mean homogeneous system (*V. J. S.* xiii. pp. 107–110). The residual difference is then considered as due to error in the assumed Constants. Dr. Dreyer's value of the Constant of Precession for 1800 thus determined (the supplementary quantities being taken from Peters' *Numerus Constans Nutationis*) is $50''{\cdot}2365$; the older values for the same epoch, and reduced to Newcomb's system, are—

Bessel	50″·214
Struve	50·232
Struve-Peters	50·236
Nyrén	50·220

The new determination is not, strictly speaking, an independent one, as Lalande's R.A.'s reduced in the manner described above depend on Piazzi's observations; but as we have seen, the result agrees well with the quantities which have been previously deduced, and considering the large number of stars used and the careful manner in which the work appears to have been done, it is useful as a check on the accuracy of what is now the generally received value of the Constant of Precession.

A. M. W. D.

The Celestial Charts of Professor C. H. F. Peters.

One of the most valuable results of the discovery of minor planets has been the production of star charts of a high degree of accuracy, and comprising stars of a low order of magnitude.

The most important maps which have hitherto been published to assist these discoveries are: (1) the Berlin Academy Star Charts, which are complete for the 24 hours of Right Ascension, and contain, in 24 maps, 40,000 stars to the ninth magnitude

many of which, however, are duplicates from the maps overlapping; and (2) M. Chacornac's Ecliptic Charts, containing, in 42 maps, over 67,000 stars, down to the thirteenth magnitude; but the series for all longitudes is not yet completed. There can be little doubt also that Harding's Atlas of 60,000 stars, though ranging from the Pole to −30° Declination, was likewise produced partly to assist in the fascinating search for minor planets instituted by Bode and Zach.

Professor C. H. F. Peters, of Hamilton College, Clinton—the distinguished discoverer of no less than 41 minor planets, being the greatest number yet discovered by any astronomer—has just published the first series of Zodiacal Charts, on which he has been engaged since 1860.

This first instalment of a most valuable work consists of 20 charts, each one covering 20^m in Right Ascension, and 5° in Declination, with overlapping margins of 1^m and 10′ respectively. The convergence of meridians is disregarded, and a uniform equal surface projection is adopted on a scale of 60 mm. to 1°. The maps have been carefully revised and compared with the heavens during the past fifteen months, with the result that no conspicuous star is omitted. The locality of the stars in the maps may be thus roughly summarised according to constellation.

1 Map	... ...	Stars in Aries.
4 Maps	... ...	,, Leo.
4 ,,	... ...	,, Virgo.
1 Map	... ...	,, Libra.
3 Maps	... ...	,, Capricornus.
5 ,,	... ...	,, Aquarius.
2 ,,	... ...	,, Pisces.
20 Maps		

The epoch of the charts is 1860·0. The stars have been plotted with great care, and the author states that the position of a star may be read off with a probable error of only 3 seconds in R.A. and 0′·2 in Declination. His desire was to represent portions of the sky in a picture that in future ages might serve as a sure basis for drawing conclusions as to changes going on in the starry heavens; and for that purpose to make as accurate and complete a delineation as the 13-inch Refractor of the Litchfield Observatory with a power of 80 would permit. This shows stars down to the fourteenth magnitude. The magnitudes of the stars in the charts are approximately indicated by the size of the disk.

Assuming No. 1 chart to be an average one, then the total number of different stars whose positions are plotted in the above 20 maps will be about 38,000. The maps have been reproduced

from the originals by photolithography, so that no error of copying has crept in.

The whole of the work, observations, reductions, and drafting, has been done by Prof. Peters without any assistance, and it is published at his own expense for gratuitous distribution.

The magnitude of the work, and the unwearied perseverance and labour necessary to complete it, and the practical result that has followed by the author's discovery of such a large number of minor planets, redound greatly to his honour and credit. Astronomers are under a great obligation to Professor Peters for the work he has just published. The value of it must be enduring, and it is therefore much to be hoped that his generous mode of distribution of copies may be modified, so that astronomers generally may be able to obtain a work that must always be useful, and in many cases absolutely indispensable.

The Mass of Jupiter.

Dr. Wilhelm Schur has published (*Nova Acta der Ksl. Leop.-Carol. Deutschen Akademie der Naturforscher*. Band xlv. No. 3) a very valuable determination of this important astronomical constant derived from heliometer measures of the satellites made at Strassburg, during the years 1874, 1876, 1879, and 1880. Altogether four heliometers (lent for the use of the German Transit of *Venus* Expedition of 1874) were employed in the research—viz., those belonging to the Observatories of Breslau, Gotha (since transferred to Strassburg), Göttingen, and Berlin. These instruments are of the same size and power.

Dr. Schur seems to have made excellent use of his opportunities, as he has secured 176 measures of distances, and 154 measures of position-angles of the four satellites. These measures have been reduced in the most careful and elaborate manner, and corrections to the elements of the orbits of the satellites obtained. Finally Dr. Schur is led to the corrected values of the mean distances of the satellites from their primary, whence the value of the mass is immediately deduced. The following are Dr. Schur's results:—

Satellite.	Reciprocal of Mass.
I.	1050·918 ± 1·125
II.	1046·026 ± 0·962
III.	1047·665 ± 0·436
IV.	1046·818 ± 0·327

Combining these by weight, the reciprocal of the mass of *Jupiter* is 1047·232 ± 0·246. The value obtained by Bessel from observations with the Königsberg heliometer was 1047·879.

This result, however, requires to be corrected for the effect of temperature, the periodic error of the micrometer screw, and for the error of the assumed value of a revolution of the screw. Dr. Schur has accordingly re-reduced Bessel's observations, taking account of these corrections, and deduced the result 1048·629, or 1047·905 (the latter of which he considers final), according to the screw value adopted. In this memoir the author has also discussed the observations of E. Luther, Triesnecker, and Santini, and deduced a value of *Jupiter's* mass from each. Finally he gives a comparison between the values of the reciprocal of the mass deduced from measures of the satellites and from planetary perturbations, the mean of the former being 1048·27, and of the latter 1049·53. Further, it is to be remarked that if Nicolai's value (1053·92) deduced from perturbations of *Juno* be rejected, all the other modern determinations range between 1047 and 1051; between which limits we may with great confidence assume the true value to lie.

Dr. Schur deserves the gratitude of astronomers for the care and assiduity with which he has pursued his investigations. It is only by continued labours of this kind that we can gradually approximate to a knowledge of the exact values of astronomical constants. A. M. W. D.

Professor Holden's Monograph of the Nebula of Orion.

The Washington Observations for 1878 contain a very important and exhaustive monograph of the central parts of the nebula of *Orion* by Professor Edward S. Holden. The author states that the main object of the Memoir is to leave such measures and descriptions of the brightest parts of the nebula of *Orion* as shall enable another person observing in after years, with the same telescope under like conditions, to say with certainty whether or no changes have occurred in these parts of this nebula. His further object was to thoroughly discuss the vast mass of material now on hand.

Before discussing the old observations it was necessary to fix upon one system of nomenclature. For the stars in the central part of the nebula, Professor Holden has adopted Bond's Catalogue reduced to 1877·0. It being also equally necessary that a rather minute system of nomenclature should be adopted to distinguish the various bright masses, dark channels, spirals, &c., of the central portion of the nebula, an Index Map is given whereon the various portions are indicated by various letters. This map is unfortunately not so clear as it might be. The boundaries of different portions are shown by white lines upon black, and it is difficult to identify a particular spot. Two or three nomenclatures of other astronomers are combined and indicated by underscoring letters or inclosing them in a right

angle, which gives a rather confused appearance. In his Introduction the author gives a list of the more important books and memoirs relating to the nebula of *Orion*, a list of drawings referred to, and of the telescopes employed to observe the nebula.

Professor Holden truly says that probably no object outside the solar system has received more attention than this nebula, and where such a mass of observations is in existence it is difficult to discriminate. No labour has been spared by the author in his endeavour to bring together reliable copies of all known drawings and copious extracts from the original observations.

Wood-cuts of the original drawings are given, all upon the same scale—that is to say, the original drawings were photographed on a scale of one inch, equal to the distance between Bond's two stars 685 and 741, or about 129 seconds of arc. Drawings made by reflectors are inverted, so that all are immediately comparable. This an important advantage, and differences and resemblances in the drawings thus become conspicuous which otherwise might escape attention; exception must however be taken to the unsatisfactory manner in which some of the wood-cuts are executed—that of Sir John Herschel's beautiful Cape drawing, for example, is very unlike the original, and could not be used for comparison. The work gives thirty-eight drawings engraved nearly on the same scale, and a reproduction of the exquisite steel-engraving of G. P. Bond, which the author considers as the most satisfactory representation of any celestial object which has yet been produced, and entirely above criticism.

The work commences with a history of the various researches on the nebula of *Orion* in chronological order, beginning with the first recorded notice of it by Cysatus in 1619, and followed by a full and complete discussion of all observations of importance from that time to the present day. The amount of laborious research required to produce such an exhaustive history must have been very great, and the result is of high value. Particular attention has been devoted to the observations of the two Herschels, Schroeter, the two Bonds, Liaponoff and Struve, Lassell, Rosse, Secchi, and D'Arrest. This portion of the work will always be of great importance as an exhaustive *résumé* of what has been observed.

The second part of the work is devoted to Professor Holden's own observations of the nebula of *Orion* made at Washington with the 26-inch telescope. These observations were commenced in 1874, and continued to 1880. They consist of eye-observations of the form, position, and relative brightness of different portions of the nebula, and micrometric measures of the position of channels and masses of the nebula relatively to stars. Particular attention was also paid to the variability of stars. On this point the author remarks that never, under the most favourable circumstances, were any stars or points of light seen or

suspected within the trapezium. The eye-observations of relative brightness of different portions of the nebula are summarised and discussed, and compared with a series of photometric observations made with a Hastings Nebula Photometer, which show agreement.

Part III. contains a summary of all the observations 1656 to 1880, discussing the connection between the nebula of *Orion* and its contained stars, the order of brightness of the various masses, and a detailed history of each mass.

The principal conclusions to which Professor Holden comes from the above discussion are :—

1. That there have been changes in the brightness of certain masses. Certain of the masses have varied in brightness during the period of the Washington observations (1874–1880). A new nebulous patch has been seen from the time of its origin, when it was stellar in appearance and faint, until now, when it is bright and of measurable dimensions.

2. That there is no evidence whatever for any change of form. The figure of the nebula of *Orion* has remained the same from 1758 to now.

Professor Holden's valuable monograph is ornamented by a photolithograph of the late Dr. Henry Draper's beautiful photograph of the nebula of *Orion*. It is impossible to discuss such an investigation as Professor Holden has undertaken without seeing that the photographic results of Dr. Draper, and the still more marvellous photographs of this nebula obtained by Mr. Common, afford far sounder and more reliable records for determining any change either in form, relative brightness, or relative position with regard to the stars than can be obtained from the examination of any eye-drawings, however carefully produced.

In an appendix to the Washington observations for 1877, Professor Holden has discussed the micrometric measurements of the six stars in the Trapezium made by Professor Hall in 1877–78, compared with those of other observers. The conclusion come to from a long and careful discussion is that after making due allowance for the unavoidable accidental and systematic errors, the comparison of all measures of the six stars of this system show their probable physical association.

Professor Holden deserves the thanks of astronomers for the painstaking and laborious research he has made into all the observations on the old method, and he is to be congratulated on bringing his labours to so successful a termination.

Professor Langley's Researches on Solar Radiation.

At the last meeting of the British Association, and also later at the French Academy, Professor Langley gave a preliminary account of the measurements he had made of the energy of radiation of the solar spectrum. The importance of this work is worthy

of more than a passing remark, since it deals not only with those radiations which are visible, but also with the radiations which have large wave-length, and whose energy is more than two-thirds of the total energy of solar radiation. Prof. Langley had first to make an instrument to carry out his researches, and the instrument required had to be excessively sensitive to radiation and also excessively exact. This instrument he completely worked out, and gave it the name of the Bolometer. As with a thermopile, the heating power of radiation is measured by deflection of a sensitive galvanometer needle; it however differs widely in every other respect. Broadly speaking, the Bolometer is made on the same principle as a Siemens' Pyrometer or a Wheatstone's Bridge, an alteration in the temperature of one of the conducting branches causing a current to pass through the coils of the galvanometer. Its sensitiveness depends on the excessive thinness of the strip of platinum or iron on which the radiation falls, and which forms part of the divided circuit. Its delicacy is such that it will show a rise in temperature in the wire of $\frac{1}{10000}$° Fahr., and when used in an ordinary manner is twenty times more sensitive than a thermopile.

With this Bolometer Prof. Langley has worked on the solar spectrum at sea-level, and at altitudes up to 10,000 feet, and he finds in all cases that the energy curve so obtained is interrupted by breaks in the invisible part of the spectrum similar to those in the visible part. His energy curves extend as far as λ 28,000, and even at this extreme limit the spectrum is traversed by bands of absorption which, by analogy and comparison with Capt. Abney's map, obtained by means of photography, and which extends to λ 12,000, he surmises to be made up of linear absorptions. These absorptions appear to be undiminished at a high altitude, confirming in a remarkable manner the observations made also at a high altitude by the latter observer, thus showing that the cause of these absorptions is to be looked for outside our atmosphere. Another point which Prof. Langley seems to have clearly demonstrated is the untrustworthiness of Cauchy's formula for dispersion. If this formula were correct, the limit of the prismatic spectrum should be nearly as much below A as E is above it. He has, however, mapped the prismatic spectrum for a distance below A as far as G is above it. This result is remarkable, since to λ 12,000 the formula holds fairly well, but beyond that point the approximate accuracy ceases, and, as Lord Rayleigh remarked at the British Association, this will necessitate a reconsideration of the properties of the ether. The establishment of this failure of Cauchy's theory was made by an ingenious combination of a diffraction grating and a prism. The grating was one of Prof. Rowland's new concave gratings of 5,000 lines to the inch, the radius of curvature being about five feet. The spectra were formed by this grating and a slit. A small slice of the superposed spectra of the different orders was then allowed to fall on a

prism which sorted out the different spectra, and then the Bolometer measured each differently refracted radiation. The energy curve thus obtained was compared with the curve obtained from the prism alone, with the result already recorded.

A comparison of the curves obtained at sea-level and at Mount Whitney, in South California, has led Prof. Langley to conclude that solar light, before it reaches our atmosphere, is decidedly bluer than we perceive it, and that its original colour is of a tint corresponding generally with that of the solar spectrum about F. These researches, which have been carried out in some cases under most trying circumstances and amidst much discomfort, are perhaps some of the most important which have been recorded during the past year, and we may expect that when fuller details are published we shall have data which will go a long way towards enabling us to calculate the average temperature of our great source of radiation.

Dr. Huggins' Method of Photographing the Solar Corona without an Eclipse.

The photograph of the spectrum of the corona taken by Professor Schuster in Egypt during the eclipse of May 17, 1882, showed that the coronal light is strongest in the part of the spectrum between G and H. This fact has led Dr. Huggins to a method of photographing the corona without an eclipse by the use of screens of coloured glass or fluid which would limit the light received by the plate to the part of the spectrum between G and H, and thus enable the coronal light to hold its own against the atmospheric glare. In applying the method, Dr. Huggins used a Newtonian reflector of 6 inches aperture and $3\frac{1}{2}$ feet focal length, with three or four plates of violet glass immediately in front of the photographic plate. In his later experiments he substituted for the violet glass a strong solution of permanganate of potash in a glass cell. Twenty successful photographs were obtained between June and September 28, in all of which Dr. Huggins considers that the coronal form is exhibited by the curved rays and rifts characteristic of the corona. Different times of exposure were given, the plates with very short exposure showing the inner corona only, whilst in those with longest exposure not only the Sun but the corona also is photographically reversed. Dr. Huggins has compared the plates taken on different days with different absorptive media interposed and with the Sun in different parts of the field, and finds that they agree *inter se*, and also with the photographs of the corona taken in Egypt during the eclipse of May last. The average heights of the inner and outer corona in the eclipse photographs were also found to be the same as in Dr. Huggins' plates. Capt. Abney has also come to the conclusion, after careful examination, that the rifts

and streamers in these plates have the same position and form as in the eclipse photographs, and that the coronal appearances are no more due to instrumental causes in the one case than in the other. Accepting this evidence of the reality of the coronal appearances on these photographs, "there can be little doubt," Dr. Huggins thinks, "that by his method under better conditions of climate, and especially at considerable elevations, the corona may be successfully photographed from day to day with a definiteness which would allow of the study of the changes which are doubtlessly always going on in it. By an adjustment of the times of exposure, the inner or outer corona could be obtained as might be desired." W. H. M. C.

The Total Solar Eclipse of 1882 *May* 17.

During the eclipse of May 17 a series of spectroscopic eye observations were made by Mr. Lockyer, especially at the beginning and end of totality. The arrangements for photographic work were made by Captain Abney, but as he was prevented from joining the expedition, Dr. Schuster took charge of that part of the work.

The chief object of the expedition was to obtain photographs of the spectrum of the corona and prominences. A series of photographs of the corona itself was also taken with exposures varying from 3 to 22 seconds. These photographs show the detailed structure of the corona, as well as an image of the comet which was visible during the eclipse, in the neighbourhood of the Sun. The photographs obtained with a complete spectroscope show, in the first place, a complicated spectrum of one of the prominences, extending far into the ultra-violet, and exhibiting, in addition to the hydrogen lines, lines of calcium and some other unknown lines. The light due to the calcium lines H and K is so bright that it is scattered in our atmosphere with sufficient intensity and appears right across the surface of the Moon.

The spectrum of the corona close to the Sun's limb is chiefly continuous, but at some distance away from the Sun a sudden decrease in the intensity of the continuous spectrum is noticed, and beyond that point many faint lines make their appearance. The solar line G is also seen to be reversed in the outer parts of the corona.

An interesting photograph was also obtained by means of the prismatic camera, which is an ordinary photographic camera with a prism placed in front of the lens. The spectrum of different prominences can be studied in the photograph thus obtained, and interesting differences between the prominences have been brought to light. The plate exposed in this instrument was sensitive in the red, and an impression reaching far

into the infra-red has been secured. Continuous rings of light corresponding to the corona line K 1474 and to D_3 are also seen independently of the prominences. A. S.

Astronomical Photography.

The past year has been signalised by the successful application of the improved dry-plate processes of photography to nebulæ as well as to comets. Dr. Huggins has obtained a photograph of the spectrum of the nebula in *Orion* with an exposure of 45 minutes, using the same spectroscope and 18-inch reflector which he employed for his photographs of star-spectra. This photograph shows a very strong bright line in the ultra-violet at wave-length 3730, in addition to the four nebular lines previously discovered by him in the visible part of the spectrum. There is also a very faint continuous spectrum, probably due to stellar light. Subsequently the late Professor H. Draper also succeeded in photographing the spectrum of this nebula. On his photographs the hydrogen line near G (λ 4340) is strong and sharp, h (λ 4101) is more delicate, and there are faint traces of other lines in the violet, but the strong line at λ 3730 is not shown. Professor Draper considers the most striking feature of the photographs to be the discovery of two condensed portions of the nebula just preceding the trapezium, which give a continuous spectrum.

Professor H. Draper has also obtained successful photographs of the nebula itself, containing most of the delicate outlying parts. More recently Mr. Common has taken photographs with his 36-inch reflector, which show all the detail visible in the best drawings, as well as the faintest stars which have been mapped.

The spectrum of Comet *a* 1882 (Wells) was photographed by Dr. Huggins on May 31. It differs greatly in the photographic portion, as in the visible part, from that of Comet *b* 1881, the cyanogen group beginning at λ 3883, and the two other groups between G and h and between h and H being absent. The continuous spectrum extends from F to a little beyond H, but does not show the Fraunhofer lines, though the lines G, H, and K are clearly seen in the spectrum of *a Ursæ Majoris* taken for comparison on the plate under the same conditions. From this Dr. Huggins infers that the part of this comet's light which gives a continuous spectrum must have been much stronger relatively to the sunlight reflected than in the case of Comet *b* 1881. In the continuous spectrum from the nucleus there are at least five places of greater brightness at λ 4769, 4634, 4507, 4412, and 4253. These are doubtless groups of bright lines, and they extend also into the coma on the side next the Sun, where the continuous spectrum is very much fainter. W. H. M. C.

On Small Displacements of the Plumb-line.

Some account was given in last year's Report of the experiments of Mr. G. H. Darwin and Mr. Horace Darwin with an instrument adapted for detecting very small changes in the vertical. It appears from their Second Report to the British Association, which is drawn up by Mr. G. H. Darwin, that the work of the experimenters has not been resumed during the past year. It will be remembered that the measurement of the lunar disturbance of gravity was found to be impracticable, and that the investigation had branched off into considerations of small changes in the vertical. The first part of this Second Report contains an account of the work of a number of Italian observers —Bertelli, Rossi, and others—in this field. The Italians commenced their observations with the intention of investigating earthquakes, and found that one branch of their subject led them on to consider slower changes in the vertical. It appears that the phenomena observed in England by the Darwins were very similar to those observed in Italy; the only important difference being the frequency of sensible earthquake shocks in the latter country.

The second part of the Report contains a mathematical investigation of the disturbance of the vertical, which may arise through the elastic yielding of the Earth's surface when the barometric pressure varies and when the tides rise and fall. The investigation is based on the hypothesis that the upper strata of the Earth are formed of an elastic solid, and numerical results are given on the supposition that the rigidity of the solid is somewhat greater than that of glass.

It is proved that the slope caused by elastic yielding at any point of the surface must be exactly proportional to the deflection of the vertical due to the attraction of the weight producing that slope. To the observer these two changes would merge into one another, and the only fact observed would be an apparent deflection of the vertical. Taking certain moderate estimates of the value of barometric gradient, it appears that the amplitude of the apparent deflection of the vertical might amount to $0''{\cdot}03$. As this is greater than the computed amplitude of deflection due directly to the Moon's attraction, it is concluded by the author as very improbable that any instrument on the Earth's surface would enable us to measure the lunar disturbance of gravity.

The next point investigated is the amount of deflection of the vertical which may be expected to result from the rise and fall of tide at places of observation near the coasts of continents. The computed deflections are considerably more than result from variations of barometric pressure, and might be sufficiently great to produce even astronomically sensible results at observatories

situated very close to the coast. Even many miles inland they would be sufficiently great in amount to be easily detected by special instruments for that purpose. The author considers, however, that it is probable that such changes would be to a large extent masked by the larger changes of a seismic origin, occurring simultaneously.

He therefore concludes that the results of observations with *exceedingly* delicate instruments are not likely to prove of much value, but the records would be likely to present a chaos of incessant changes, of which no satisfactory account could ever be given.

He considers, however, that the use of somewhat coarser instruments (such as those of the Italians) may lead to important results concerning the seismic and slower quasi-seismic changes taking place in the upper strata of the Earth.

Investigations Relating to the Tides.

Mr. G. H. Darwin also presented two other papers relating to the Tides to the British Association at the late meeting at Southampton. The first of these has reference to the method of reduction employed in deducing the values of the tides of long period from the records of tidal observation. We need here only mention that, in consequence of a mistake (detected by Prof. J. C. Adams), the published results assign a value to the synodic fortnightly tide which is fictitious. It is proposed that these results should be corrected under the supervision of a committee consisting of Prof. Adams and Mr. Darwin.

The other paper is the abstract of an investigation contributed to the new edition of Thomson and Tait's *Natural Philosophy*, now in the press. The values of the lunar fortnightly and the elliptic monthly tides, as observed at a number of stations and in a series of years, are reduced by the method of least squares, and the result shows that it is probable that the height of those tides is about two-thirds of what it would be if the Earth's mass were absolutely rigid.

From this it may be concluded as probable that the Earth as a whole has at least as great a modulus of rigidity as if it were formed of steel. Although the number of observations is considerable, being thirty-three for each class of tide, yet the concordance between the results for different years and different places is not very satisfactory, and it will be necessary to await the accumulation of more results at places more widely scattered over the Earth's surface to evaluate exactly the degree of rigidity possessed by the Earth's mass.

Oppolzer's Treatise on the Calculation of the Orbits of Comets and Planets.

The first volume of Professor Oppolzer's *Lehrbuch zur Bahnbestimmung der Kometen und Planeten* was issued in 1870, and the second volume in 1879; and a notice of the complete work appeared in the Annual Report for 1880 (vol. xl. p. 243). The first volume contained 353 large octavo pages, and the second 635, and we have now to mention that a second edition of the first volume, containing 683 pages, has just been published. The original first volume of 1870 is thus entirely superseded, and the work, as a whole, consists of the volumes of 1879 and 1882, containing in all more than 1300 pages. The first volume relates to the coordinates in their mutual relations and their relations to the time, with full applications of the methods of taking account of Aberration, Precession, Nutation, &c., and to the determination of parabolic orbits and orbits in general in which no supposition is made with regard to the eccentricity. There are about 250 pages of tables in the volume, the largest of which is a modified Barker's table giving log M, where

$$M = \frac{\sqrt{2}}{k} \tan \tfrac{1}{2} v + \tfrac{1}{3} \frac{\sqrt{2}}{k} \tan^3 \tfrac{1}{2} v$$

which was calculated for the work.

All the formulæ and processes and tables are given with abundant fulness and detail, and the work, as a whole, is quite unique in astronomical literature. It is an elaborate and complete treatise on the very part of mathematical astronomy which most required comprehensive treatment in a single work, and which seemed to have but very slight chance of obtaining it. The book is beautifully printed and got up in every way, and Dr. Oppolzer has earned the congratulations and thanks of those interested in astronomical calculation, on which he has conferred a real service.

Bibliography of Astronomy.

The valuable bibliographical work published by M. Houzeau in vol. i. of the *Annals of the Brussels Observatory*, under the title "Répertoire des Constantes de l'Astronomie," was the forerunner of a still more comprehensive work, one volume of which has recently been published.

The *Bibliographie Générale de l'Astronomie* has been prepared by M. Houzeau, the director, and M. Lancaster, the librarian of the Brussels Observatory. It had occurred to the latter some time back to undertake a continuation of Lalande's *Bibliographie*

Astronomique, and in 1879, on M. Houzeau taking the directorship of the Observatory, the work was commenced.

This Bibliography claims to be a methodical Catalogue of all books, memoirs, papers, and astronomical observations published since the invention of printing to the year 1880. It is divided into three important sections, each of which will form a separate volume.

1. Independent and separately-published works on astronomy.
2. Memoirs and papers published in the Transactions of scientific Societies and in periodical publications.
3. Observations of Observatories.

The vast mass of scientific work at the present day is to be found in the publications of learned Societies; and so MM. Houzeau and Lancaster have wisely commenced the publication of the work with the second volume. A very cursory examination of it is enough to indicate the enormous labour involved in the undertaking, and a careful study of it reveals that the research has been carried out in a minute and exhaustive manner which reflects the greatest credit upon the authors and puts astronomers under a lasting obligation to them.

In a work of this magnitude the method of arrangement, and the facility afforded by it for finding a research on a particular subject, is of vital importance to its utility.

The volume under consideration is divided into nine sections.

1. The History and Study of Astronomy .	Comprising	17	chapters
2. Astronomical Biographies	„	2	„
3. Spherical Astronomy	„	34	„
4. Theoretical Astronomy	„	14	„
5. Celestial Mechanics	„	14	„
6. Physical Astronomy	„	47	„
7. Practical Astronomy	„	31	„
8. Monographs on the principal members of the Solar System	„	113	„
9. Stellar Astronomy	„	11	„

The references in each chapter are arranged under authors' names in chronological order, giving the full title of the paper and the abbreviated designation of the publication. An exception to this is made in the case of the Astronomical Biographies, which are arranged alphabetically, according to the names of the astronomers. The date affixed is that of publication, but where a paper has been presented to a Society some material time before its publication, this is given also, in brackets.

The principle adopted for the brief titles of publications is, in the case of Academies, to give the locality of the Society and indicate the particular publication by three letters. The *Monthly*

Notices would be thus given: "Londres MNt." In the case of periodical publications, these are designated by three initials only, without reference to locality; the *Connaissance des Temps* being "CdT." A very full and explicit index and key to the abbreviations is given, which enables any work to be readily identified. An appendix to the volume gives an alphabetical table of authors, with a very complete index to their researches.

As an example of the amount of information afforded by this work, it will be enough to mention that sixty-two columns are devoted to references to observations of lunar mountains, arranged in the alphabetical order of their names.

In their introduction the authors give some interesting statistical information. From this it appears that out of about 18000 articles in different languages referred to in the Bibliography, 5991 are in French, 5809 in English, and 4438 in German. The three principal sources of astronomical articles are the *Monthly Notices*, furnishing 1573, the *Comptes Rendus*, 1481, and *Astronomische Nachrichten*, 1918 papers respectively. A table is also given showing by a curve the number of articles published each year from 1600 to 1880, which reveals in a novel and interesting manner the progress of astronomical research.

The authors have satisfactorily performed the most laborious part of their undertaking, and though omissions in such a work are inevitable, they do not appear on examination to be very numerous. It is not too much to say that the work, so far, is of incalculable value, and that MM. Houzeau and Lancaster deserve the gratitude of astronomers for accomplishing it in so complete and satisfactory a manner.

Papers read before the Society from February 1882 *to February* 1883.

1882.

Mar. 10. The Transit of *Mercury* 1881, November 7, observed in New South Wales. H. C. Russell.

Note on the north polar distance of the star Lacaille 4342. David Gill.

Observations of the Transit of *Mercury* 1881, November 7, made at Honolulu, Sandwich Islands. C. H. Rockwell.

Observations of Comet III. 1881, made at Windsor, New South Wales. J. Tebbutt.

Observations of the lunar eclipse 1881, December 5. J. Rand Capron.

Note on the places of three stars in the Armagh Catalogue. Rev. T. R. Robinson.

Measures of Sir John Herschel's double stars made at the Observatory, Sydney, together with a list of new double stars. H. C. Russell.

Orbits of meteor-streams deduced from observations made in Hungary during the years 1871–80. R. de Kövesligethy.

On the correction to the horizontal diameter of the Moon from the observations made between 1851 and 1858. J. Campbell and E. Neison.

Revision of 21 places in the red half of the solar spectrum, with a Rutherfurd diffraction grating, at Madeira, during the summer of 1881. Prof. C. Piazzi Smyth.

Observations of occultations of stars by the Moon and phenomena of *Jupiter's* satellites, made at the Royal Observatory, Greenwich, in the year 1881. Astronomer Royal.

Notes on M. Loewy's remarks relative to the wedge-extinction method of stellar photometry. Prof. C. Pritchard.

Note on a term in the perturbations of the Moon due to the action of *Mars*. E. Neison.

Observations of occultations of stars by the Moon, and of phenomena of *Jupiter's* satellites made at the Radcliffe Observatory, Oxford. E. J. Stone.

Réponse à la communication faite à la Société Royale Astronomique par M. Marth, au sujet de mon appareil pour la détermination des flexures. M. Loewy.

On the observation of the Transit of *Venus* by the dispersion-parallelopipedon. Prof. C. V. Zenger.

Spectroscopic results for the motions of stars in the line of sight, obtained at the Royal Observatory, Greenwich in the year 1881. No. V. Astronomer Royal.

A new method of bright-wire illumination for position micrometers. S. W. Burnham.

Sextant observations of Comet *b*, 1881. Capt. D. W. Barker.

April 14. On the inclination of the ring of *Saturn* to its orbit, deduced from Washington Observations. Prof. E. S. Holden.

Conjunctions of the interior satellites of *Saturn*. Prof. A. Hall.

On the best mode of undertaking a discussion of the observations of contact to be made at the approaching Transit of *Venus*. David Gill.

Errata in the first Melbourne General Catalogue of Stars. R. L. J. Ellery.

Remarks on the instructions for observing the Transit of *Venus* formulated by the Paris International Conference. Prof. S. Newcomb.

The variable star *β Ursæ Minoris*. T. E. Espin.

On some results obtained from the meridian observations of *Mars* at the Opposition of 1877. E. J. Stone.

Note on Mr. Neison's paper on the corrections to Adams's semi-diameter of the Moon. E. J. Stone.

Observations of the companion of *Sirius*. Prof. A. Hall.

Alleged errors in the time-record of observations of the Transit of *Venus*, 1874, at Hermitage, Rodriguez. Lieut. W. U. Moore.

May 12. On a supposed periodical term in the values found for the coefficient of the parallactic inequality. E. Neison.

The nebula near *Merope*. T. W. Backhouse.

Observations of the phenomena of *Jupiter's* satellites made at Mr. Edward Crossley's Observatory, Bermerside, Halifax. J. Gledhill.

Note on the illumination of micrometers. A. A. Common.

Elements of the orbit of Comet *Wells*. A. Graham.

An examination of the Roorkee observations of the Transit of *Venus*. Col. J. F. Tennant.

The great Sun-spots of April 1882. H. Pratt.

Note on an apparatus for determining those errors of astronomical observations which are caused by the flexures of an instrument, and by defects in the shape of its pivots. A. Marth.

Determination of the orbit of η *Cassiopeiæ*. J. B. Coit.

On the spectrum of Comet *a*, 1882 (Wells), observed at the Royal Observatory, Greenwich. Astronomer Royal.

Discussion of the observations of γ *Draconis*, made with the Greenwich reflex zenith-tube during the years 1857 to 1875 inclusive. A. M. W. Downing.

Note on a photograph of the nebula in *Orion*. A. A. Common.

On the solar spots of April and May, 1882. Rev. F. Howlett.

June 9. Measures of the companion to *Sirius*. S. W. Burnham.

The meridian photometer. Prof. E. C. Pickering.

Remarques à propos des récentes observations de M. Schiaparelli sur la planète *Mars*. Dr. F. Terby.

On the present state of the theory of the sidereal system. Maxwell Hall.

Transits of the red spot across the apparent central meridian of *Jupiter*, with the corresponding longitudes. Prof. C. W. Pritchett.

Double star observations made in 1879 and 1880, with the $18\frac{1}{2}$-inch Refractor of the Dearborn Observatory. S. W. Burnham.

The solar eclipse, 1882, May 16. Rev. S. J. Perry.

Observations of Comet *b*, 1881. T. W. Backhouse.

On photographs of the nebula in *Orion*, and of its spectrum. Dr. H. Draper.

On the spectrum of Comet *Wells*. N. C. Dunér.

On the possible existence of perturbations in cometic orbits during the formation of nuclear jets, with suggestions for their detection. C. E. Burton.

Note on lunar photographs taken after enlargement of the primary image by an eyepiece. C. E. Burton.

On the variable star U *Cephei*. G. Knott.

Sextant observations of Comet *b*, 1881. Capt. J. F. Parson.

Some remarks on Prof. Newcomb's paper on the instructions for observing the Transit of *Venus* formulated by the Paris International Conference. E. J. Stone.

Note on M. Loewy's communication referring to an apparatus for determining flexure errors. With some remarks on Prof. Houzeau's (and M. Schäberle's proposal) on the same subject. A. Marth.

Note on the best method for determining the errors of division of circles and scales. A. Marth.

Ephemeris for physical observations of *Jupiter*. A. Marth.

Further spectroscopic observations of Comet *a*, 1882 (Wells), made at the Royal Observatory, Greenwich. Astronomer Royal.

Curves showing the changes in the adopted diameter of the Moon as given by the observations in the Greenwich Lunar Reductions 1750 to 1830. E. J. Stone.

Elements of Comet *Wells* obtained graphically. F. C. Penrose.

Nov. 10. Ephemerides of the satellites of *Saturn*, August to November 1882. A. Marth.

Ephemeris of the satellite of *Neptune*, 1882–1883. A. Marth.

Observations of Comet *a*, 1882, made at the Radcliffe Observatory, Oxford. E. J. Stone.

On the partial eclipse of the Sun, 1882, May 17, observed at Vizagapatam. A. V. Nursing Row.

Observation of Comet *Wells*. L. G. Puckle.

Spectroscopic observations of Comet *Wells*. Dr. de Konkoly.

Ephemerides of the satellites of *Saturn*, December 1882 to March 1883. A. Marth.

Addition to the Ephemeris for physical observations of *Jupiter*: on the motion of the white spot. A. Marth.

Réponse à M. Marth. M. Loewy.

On the solution of Kepler's problem. Professor C. V. Zenger.

Observations of Comet *b*, 1882, made at Windsor, New South Wales. J. Tebbutt.

Elements of Comet *b*, 1882. W. H. Finlay and W. L. Elkin.

The fireball radiants of August 9–11. W. F. Denning.

The electric light in observatories. W. S. Franks.

The markings on *Jupiter*. W. F. Denning.

Elements of Comet III. (Schäberle), 1881. H. T. Vivian.

On observations of Comets 1881 I. and II., of Wells's Comet, and of the Great Comet (*b*) 1882, made at the Royal Observatory, Cape of Good Hope. David Gill.

Notes on the Great Comet (*b*) 1882. David Gill.

The Great Comet (*b*) 1882: disappearance at the Sun's limb. W. H. Finlay.

Observations of the Great Comet (*b*) 1882. W. L. Elkin.

On a probable Assyrian Transit of *Venus*. Rev. S. J. Johnson.

The Great Comet (*b*) 1882. F. C. Penrose.

On certain deviations from the law of apertures in relation to stellar photometry, and on the applicability of a glass wedge to the determination of the magnitudes of coloured stars. Professor C. Pritchard.

Observations of Comets *a*, *b*, and *c*, 1882, made at the Royal Observatory, Greenwich. Astronomer Royal.

The solar eclipse of 1882, May 17, observed at Meerut, India. Major A. Burton-Brown.

Sextant observations of the Great Comet (*b*) 1882. Captain G. Pochrane.

Dec. 8 Observations of the Great Comet (*b*) 1882, made at the Melbourne Observatory. R. L. J. Ellery.

Observations of the Great Comet (*b*) 1882, made at the Sydney Observatory. H. C. Russell.

Observations of Comet *Wells* (*a*) 1882, made at Windsor, New South Wales. J. Tebbutt.

Observations of the Great Comet (*b*) 1882. A. V. Nursing Row.

Observations of the Great Comet (*b*) 1882 (extract from a letter to the Rev T. W. Webb). J. T. Stevenson.

Observations of the Great Comet (*b*) 1882, made at the Observatory, O'Gyalla, Hungary. Dr. N. de Konkoly.

The star gauges of Sir W. Herschel, reduced to 1860. Prof. E. S. Holden.

On photographs of the Great Comet (*b*) 1882, obtained at the Royal Observatory, Cape of Good Hope. David Gill.

Observation of the Transit of *Venus* 1882, December 6, made at Crowborough, Tunbridge Wells. C. L. Prince.

Observations of the Great Comet (*b*) 1882, made at the Cambridge Observatory. Prof. J. C. Adams.

On Newton's solution of Kepler's problem. Prof. J. C. Adams.

Observations of the Great Comet (*b*) 1882. Rev. J. Reed.

Observation of the Transit of *Venus* 1882, December 6. W. E. Cooper.

1883.

Jan. 12. Ephemeris of the satellites of *Uranus*, 1883. A. Marth.

Observation of the Transit of *Venus* 1882, December 6, made at the Glasgow Observatory. Prof. R. Grant.

The Transit of *Venus* 1882, December 6, observed at the Allegheny Observatory. Prof. S. P. Langley.

Observations of the solar spots, November 1882. F. Brodie.

Observation of the Transit of *Venus* 1882, December 6, made at Fernhill, Isle of Wight. F. Brodie.

The Aquariads of April 29 to May 3. W. F. Denning.

Observations of the Great Comet (*b*) 1882. B. J. Hopkins.

Le passage de *Vénus* (1882, Dec. 6) observé à l'Observatoire, Moncalieri. F. Denza.

Physical observations of the Great Comet (*b*) 1882. C. L. Prince.

Sextant observations of the Great Comet (*b*) 1882, made on board the ship "Earnock." Capt. G. F. Parson.

Sextant observations of the Great Comet (*b*) 1882, made on board the ship "Superb." Capt. D. W. Barker.

Observation of the Transit of *Venus* 1882, December 6, made on board H.M.S. "Northampton" at Antigua, West Indies. J. R. Walker (and other officers).

Observation of the Transit of *Venus* 1882, December 6, at Marseilles. Rev. S. J. Johnson.

Observation of the Transit of *Venus*, 1882, December 6. Rev. R. P. Davies.

Observations of phenomena of *Jupiter's* satellites, made at the University Observatory, Durham, in the year 1882. G. A. Goldney.

Postscript on a communication made to the Royal Astronomical Society in November last, on stellar photometry. Prof. C. Pritchard.

Observations of *Jupiter*. W. F. Denning.

The Great Comet (*b*) 1882. L. A. Eddie.

Observation of the Transit of *Venus* 1882, December 6, made near Bath. M. Horner.

Reduction of latitude and logarithm of the Earth's radius, with Col. Clarke's value of the Earth's compression. E. J. Stone.

Meteors and meteorology. R. A. Proctor.

The orbit of the Great Comet (*b*) 1882. F. C. Penrose.

Note upon the longitude of Madras, Singapore, and Batavia. Prof. J. A. C. Oudemans.

Spectroscopic results for the motions of stars in the line of sight obtained at the Royal Observatory, Greenwich, in the year 1882. No. VI. Astronomer Royal.

The spectrum of the great Sun-spot of 1882, November 12–25, observed at the Royal Observatory, Greenwich. Astronomer Royal.

Note on William Ball's observations of *Saturn*. Prof. J. C. Adams.

List of Public Institutions and of Persons who have contributed to the Library &c. since the last Anniversary.

Her Majesty's Government.
Her Majesty's Government in Australia.
Her Majesty's Government in India.
The Norwegian Government.
The Lords Commissioners of the Admiralty.
British Association for the Advancement of Science.
British Horological Institute.
Geological Society of London.
Institute of Actuaries.
Meteorological Office.
Meteorological Society.
Photographic Society of Great Britain.
Physical Society of London.
Royal Asiatic Society.
Royal Geographical Society.
Royal Institution.
Royal Observatory, Greenwich.
Royal Society of London.
Royal United Service Institution.
Selenographical Society.
Society of Arts.
University College, London.
Zoological Society of London.
Bedfordshire Natural History Society.
Belfast Natural History and Philosophical Society.
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Dublin, Royal Irish Academy.
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Batavia Magnetical and Meteorological Observatory.

Berlin, Physical Society.
Berlin, Royal Academy of Sciences.
Berlin, Royal Observatory.
Berlin, Royal Prussian Geodetic Institute.
Berne, Central Meteorological Institute.
Bologna, Academy of Sciences.
Bordeaux, Society of Physical and Natural Sciences.
Boston, American Academy of Arts and Sciences.
Boston Scientific Society.
Brussels, Royal Observatory.
Buda-Pesth, Hungarian Academy of Sciences.
Calcutta, Asiatic Society of Bengal.
Cape Town, South African Philosophical Society.
Chapultepec Observatory.
Cherbourg, National Society of Sciences.
Chicago, Dearborn Observatory.
Cincinnati Observatory.
Cincinnati, Ohio Mechanics' Institute.
Coimbra, Observatory of the University.
Connecticut Academy.
Copenhagen, Royal Academy of Sciences.
Cordoba, National Argentine Observatory.
Geneva Observatory.
Geneva, Society of Physics and Natural History.
Genoa, Society of Literature and Science.
Göttingen, Royal Society of Sciences.
Haarlem, Musée Teyler.
Halle, Imperial Leopold-Caroline Academy.
Harvard College Astronomical Observatory.
Helsingfors, Finnish Society of Sciences.
Leghorn, Technical and Nautical Institute.
Leipzig, Astronomische Gesellschaft.
Leipzig, Royal Saxon Society of Sciences.
Lisbon Geographical Society.
Madison, Washburn Observatory.
Melbourne Observatory.
Melbourne, Royal Society of Victoria.
Milan, Royal Observatory.
Moncalieri Observatory.
Montreal, Geological Survey of Canada.
Moscow Observatory.
Mozambique Geographical Society.
Munich, Royal Bavarian Academy.
Munich, Royal Observatory.
Neuchatel, Society of Natural Sciences.
New York, Astor Library.
Ottawa, Canadian Meteorological Office.
Padua Observatory.
Palermo Observatory.
Paris, Academy of Sciences.

Paris, Bureau des Longitudes.
Paris, Dépôt Général de la Marine.
Paris, Ecole Polytechnique.
Paris, International Committee of Weights and Measures.
Paris, Mathematical Society of France.
Paris Observatory.
Paris, Philomathic Society of France.
Philadelphia, American Philosophical Society.
Philadelphia, Franklin Institute.
Prague Observatory.
Pulkowa Observatory.
Rio de Janeiro, Imperial Observatory.
Rome, Italian Meteoric Association.
Rome, Italian Spectroscopic Society.
Rome, Pontifical Academy dei Lincei.
Rome, Royal Academy dei Lincei.
St. Petersburg, Imperial Academy of Sciences.
St. Petersburg, International Polar Commission.
San Fernando Observatory.
Sydney, Government Observatory.
Sydney, Royal Society of New South Wales.
Tasmania, Royal Society.
Tiflis, Physical Observatory.
Toulouse, Academy of Sciences.
Turin, Italian Meteorological Association.
Turin, Observatory of the Royal University.
Turin, Royal Academy of Sciences.
Upsala, Royal Society of Sciences.
Vienna, Imperial Academy of Sciences.
Washington, Smithsonian Institution.
Washington, United States Chief Signal Office.
Washington, United States Coast and Geodetic Survey.
Washington, United States Naval Observatory.
Yale College Observatory.
Yokohama, Seismological Society of Japan.
Editors of the American Journal of Science.
Editors of the American Journal of Mathematics.
Editor of the Analyst.
Editor of the Astronomical Register.
Editor of the Astronomische Nachrichten.
Editor of the Athenæum.
Editors of the Bulletin des Sciences Mathématiques, &c.
Editor of the English Mechanic.
Editor of the Journal of Science.
Editor of Die Naturforscher.
Editors of the Observatory.
Editors of La Revue Scientifique.
Editor of Sirius.
Editor of the Sidereal Messenger.

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Dr. R. Wolf.

ADDRESS

Delivered by the President on Presenting the Gold Medal of the Society to Dr. Benjamin Apthorp Gould.

Gentlemen,—

Your Council have awarded the Gold Medal of the Society to Benjamin Apthorp Gould for his *Uranometria Argentina*.

Dr. Gould is an astronomer who has held a leading position amongst the cultivators of our science for many years; and a reference to the "Royal Society's Lists of Scientific Papers" will find him credited with no less than fifty-five papers. These papers treat of almost all branches of our science; and some of them, such as the "Reduction of D'Agelet's Observations," are works of considerable extent and of great value. These works cannot have been without their influence in guiding the decision of your Council in the award of the Medal, but it has been upon Dr. Gould's direction of the work of the Cordoba Observatory that attention has been chiefly concentrated.

The astronomical results contained in the *Uranometria Argentina* constitute but a small, and in my opinion not the most valuable, portion of those which have been obtained by Dr. Gould since he assumed the direction of the Cordoba Observatory; but although the observations for the Southern Zones are understood to have been completed, and one volume of results has already been published, your Council have thought it undesirable to await the complete publication of these results before marking, in the most emphatic manner in their power, their high appreciation of the skill and energy with which Dr. Gould has utilised the resources placed at his disposal by the liberality of the Government of the Argentine Republic.

The work for which the Medal has been chiefly awarded may be considered an extension of Argelander's scale of magnitudes to all the stars which can be seen by a good eye without instrumental aid between 10° North Declination and the South Pole, together with a series of charts exhibiting, on a stereographic projection, the positions of all these stars to the sixth magnitude, and a proposed revision of the boundaries of the southern constellations.

The work is of a class which is not usually undertaken at our principal Observatories, for it requires neither an elaborate instrumental equipment nor that technical skill on the part of the observers which can only be acquired by long continued practice; but Dr. Gould, on his arrival, with four assistants, at Cordoba, in the September of 1870, found that the instruments

which had been ordered from Europe for the Observatory had not been received; and the disorganisation of scientific matters on the Continent from the war then in progress rendered it probable that there might be some considerable delay before these instruments could be delivered. Under these circumstances Dr. Gould, encouraged by the experience which he had gained, and by the success which had attended a somewhat similar effort, on a smaller scale, made during the mounting of the Transit Circle at the Albany Observatory in 1858, determined to undertake the work for which your Medal is this day awarded.

In the absence of any standard of absolute brightness, the determination of stellar magnitudes can only be relative, and the scale in which they are expressed must be an arbitrary one. The second Herschel, whilst at the Cape, determined the light received from the principal Southern stars in terms of the combined light of α^1 and α^2 *Centauri* as an unit, and he pointed out that by a slight modification of the scale in general use it would be possible to make that scale a photometric one, and the amount of light received inversely proportional to the square of the number which expressed the magnitude. But although some such modification as that proposed by Herschel would be a decided improvement, if the ground were not already preoccupied, yet our conventional system of magnitudes, as practically exhibited with some approach to scientific precision in the *Uranometria Nova*, has received such general acceptance from astronomers that probably Dr. Gould was well advised in adopting it for his Southern Uranometria. To secure consistency between the estimations of magnitude by the different observers and the practical adoption of Argelander's scale, and its extension to stars of the seventh magnitude, Dr. Gould selected, from the *Uranometria Nova*, 1800 stars between the parallels of 5° and 15° North Declination which culminated at nearly the same altitudes at Bonn and at Cordoba. The magnitudes of these stars were estimated by all the four observers to whom the work at Cordoba was to be entrusted, and the results obtained were carefully compared with the magnitudes of the *Uranometria Nova* and, I presume, in cases of discordances reconsidered. It was found that the estimations of the four observers were in perfect accord, to tenths of a magnitude, in the case of 722 of these stars; in the other cases the discordances did not usually exceed the tenth of a magnitude and never exceeded two-tenths, except in cases where there were peculiarities of colour or the presence of some companion star to disturb the estimations. Dr. Gould determined to adopt as his standards of magnitude only those stars upon which the agreement of the four observers was perfect.

But to facilitate the comparisons of the Southern stars with these standards, stars in two regions south of Declination 55° were selected and carefully compared by all the four observers with the standards in the principal type-belt, and thus a secondary set of standards, more conveniently situated for direct

comparison with the Southern stars, was established. The work was then distributed among the four observers, and appears to have been completed about the end of the year 1873.

It will give some indication of the magnitude of the work when I mention that the number of estimations made for the formation of the *Uranometria Argentina* exceeded 46,000.

These estimations of stellar magnitude must be considered as the corpus of the work for which your Medal has been awarded, but Dr. Gould has carefully discussed the results, and compared them with nearly all the materials which were available for the purpose, and, in particular, he has compared his estimations of the magnitude of the brighter stars with results obtained from a discussion of the photometric observations of the second Herschel and of Seidel. The results of this comparison are generally satisfactory, although there appear some slight indications of a change of scale within the range of the four magnitudes compared with Herschel's measures.

The comparison of the Cordoba magnitudes with those of Lacaille, Herschel, and other astronomers, has revealed some cases of marked discordance; but as Dr. Gould has had the great advantage of having his predecessors' work before him, and has been able to refer to the stars themselves for verification and, if need be, correction of his results, it is not probable that these discordances can be due to accidental errors in the Cordoba estimations. In the Notes appended to the Catalogue such cases are carefully pointed out, and discussed whenever sufficient materials existed for the purpose. These Notes will be of great value to our Southern astronomers, and are certain to lead to successful investigation in the interesting field of stellar variation.

The maps published by Dr. Gould are fourteen in number, one of which is a skeleton map showing the proposed revision of the Southern boundaries of the constellations. Each map has been directly compared with the portion of the sky to which it refers before publication, and the greatest care has been taken to reproduce, as closely as possible, the gradations of light over the region of the Milky Way. The position of the Northern Pole of the Galactic Circle is fixed by Dr. Gould at R.A. $12^h\ 41^m\ 20^s$, Decl. North $27°\ 21'$ for the epoch 1875·0. The maps are beautifully executed, and will well repay examination.

The materials collected by Dr. Gould on the Uranometria of the Southern heavens are far more complete and accurate than any which previously existed; and he has, therefore, been naturally led to discuss their bearing on those great questions of the constitution of our stellar universe which offer so fascinating and inexhaustible a field for philosophical speculation.

The results which Dr. Gould has obtained are in general accordance with those of previous investigators on the subject. It appears to be clearly proved that distance is one of the most important factors in producing differences of apparent bright-

ness in the stars; but the agreement between the number of stars of different magnitudes and the number which might be expected if these changes of apparent brightness depended solely on distance is not perfect over any large range of magnitudes. There appears to be a decided preponderance in the number of the brighter stars. It is possible that this preponderance may be partially due to the conventional scale of magnitudes not being a truly photometric scale; and it is necessary, before any close agreement can be expected between the number of stars of the different magnitudes and those computed on the assumption of distance being the sole factor of variation, that the number of stars in a group should be sufficiently great to insure that the mean intrinsic brightness of the stars of each group should be constant, a condition which can only be secured when a considerable number of stars are included in each group, for there are certainly proved variations of intrinsic brightness amongst the stars in a higher proportion than 300 : 1. But, although Dr. Gould had these possible sources of error before his mind, he has been led, after a careful discussion of his own observations, to infer that the preponderance of the brighter stars is due to the existence of a stellar cluster consisting of some four or five hundred stars, of which our own system is supposed to be a member. The position of the northern pole of the medial plane of this belt of stars has been fixed by Dr. Gould at R.A. $11^h\ 25^m$, N.P.D. 60°, whilst that of the Galactic Circle is at R.A. $12^h\ 41^m$, N.P.D. 62° 39′. That there is a striking crowding of bright stars towards the portion of the heavens to which Dr. Gould calls attention is an undoubted fact, and one which had previously attracted notice. It is also proved by Dr. Gould that the number of stars of the different magnitudes, which remain after the abstraction of the stars of this supposed group, agrees more closely than before with the computed number on the assumption that the changes in brightness depend solely on distance. But whether these facts are sufficient to prove our power of discriminating between the stars of this belt, and that general condensation of matter which gives rise to the appearance of the Milky Way is a point upon which I can form no very positive opinion. I think, however, that the values of annual parallax and of relative brightness, which have been found for some of the stars of this belt show that, if it exists as an isolated cluster, it is one of vast extent and great complexity. Looking out from this mere speck of an Earth on the space which surrounds me, and recognising, as I must, the awful and almost inconceivable distances that separate me from the nearest of the stars, compelled to acknowledge that every one of these twinkling points is as much an independent source of light and heat as our own Sun, that every increase of optical power brings a large proportionate number of other stars into view, and in entire ignorance of the position of my point of view amongst these stars, I feel my inability to firmly grasp the geometrical, much less the

physical, constitution of such an universe. I cannot conceive space without limits, or the possible nature of a boundary of such space. However much, therefore, my mind may revel for a time and rejoice in its almost unfettered liberty amid such speculations, yet it finds no Mount Ararat upon which to rest the sole of its foot, and it soon gladly returns to the ark of experiment and observation upon which the foundations of our science have been laid, and the superstructure, if slowly, yet securely raised.

Although, therefore, from the constitution of my mind, and training, I am perhaps unable to do full justice to this, the speculative part of Dr. Gould's work, I can speak with the greatest confidence of the value of the observational results contained in the *Uranometria Argentina.* It is a work of very considerable extent; it has been planned with great care; and executed with the most scrupulous attention to details. It will remain an enduring record of the relative brightness of the Southern stars for its epoch; and will be accepted for many years as the chief authority upon questions of their magnitude; and it is certain, from its very success, to incite other astronomers to efforts in the same direction—efforts which must ultimately lead to its being replaced by something more extensive, something even yet more accurate.

No higher praise can, I believe, be given to work of the class. In our science, at least, men do rise "on stepping-stones of their dead selves to higher things." I am certain that the award of this Medal by your Council to Dr. Gould will be received with the greatest satisfaction by the Fellows of this Society, and by practical astronomers of all nationalities, as a fitting tribute to good work done for the advancement of their science.

Earl of Crawford and Balcarres.

My Lord,

Will you forward, through the representative of the Argentine Republic, this Gold Medal to Dr. Benjamin Apthorp Gould, with the assurance of our high appreciation of the skill, energy, and success, with which he has directed the work of the Cordoba Observatory, and our hopes that his efforts for the advancement of our science may be long continued and equally successful in the future?

The Meeting then proceeded to the election of the Officers and Council for the ensuing year, when the following Fellows were elected :—

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E. J. Stone, Esq., M.A., F.R.S., Radcliffe Observer.

Vice-Presidents.

J. C. Adams, Esq., M.A., LL.D., D.C.L., F.R.S., Lowndean Professor of Astronomy, Cambridge.
Sir G. B. Airy, K.C.B., M.A., LL.D., D.C.L., F.R.S.
W. H. M. Christie, Esq., M.A., F.R.S., Astronomer Royal.
J. R. Hind, Esq., LL.D., F.R.S., Superintendent of the *Nautical Almanac*.

Treasurer.

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Rev. Charles Pritchard, M.A., D.D., F.R.S., Savilian Professor of Astronomy, Oxford.
A. Cowper Ranyard, Esq., M.A.